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DYNAMICS OF PLAYA LAKES IN THE TEXAS HIGH PLAINS

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August 31, 1974

Final Report

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16. Abstracts The objectives of this investigation were to evaluate the possibilities of using satellite imagery to determine time-space relations of precipitation-runoff-infiltration-evaporation-transpiration to the geology-geomorphology of lake basins on the Southern High Plains of West Texas. Three lake basins, similar to the tens of thousands on the Southern High Plains, were originally investigated for this study; however, receipt of initial imagery showed the basins too small for measurement of water fluctuations. A fourth, but much larger test site, was then designated. NASA-furnished ERTS-1 imagery was studied by both optical and electronic methods, the film data later being compared to digitized data from computer tapes. Although recognizable from ERTS-1 imagery, detailed water fluctuations in small playa lake basins of less than 12,141 sq. m. cannot be accurately monitored. ERTS-1 imagery was also used to trace the surface moisture paths of local storm cells.

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LIST OF ABBREVIATIONS AND SYMBOLS

Band L	-	Bausch and Lomb
Ca	-	Calcareous
CAL	-	Calcareous
CL	-	Inorganic clays: low to medium plasticity, gravelly clays, sandy and silty clays
EROS	-	Earth Resources Observatory Systems
ERTS	-	Earth Resource Technology Satellite
ESIAC	-	Electronic Satellite Image Analysis Console
Frags	-	Fragments
Gyp	-	Gypsum
HCl	-	Hydrochloric acid
Impreg	-	Impregnated
Kdc	-	Cretaceous Duck Creek Formation
Kki	-	Cretaceous Kiamichi Formation
ML	-	Inorganic silts, very fine sands, silty or clayey silts
MSS	-	Multispectral Scanner
NASA	-	National Aeronautics and Space Administration
Rex	-	Reacts with
SC	-	Clayey sands, sand-clay mixtures
SM	-	Silty sands, sand-silt mixtures
SP	-	Poorly graded sands, gravelly sands, little or no fines
SRI	-	Standford Research Institute
W/o	-	Without
Xls	-	Crystals

PREFACE

A. OBJECTIVE

The objectives of this investigation were to evaluate the possibilities of using satellite imagery to determine time-space relations of precipitation-runoff-infiltration-evaporation-transpiration to the geology-geomorphology of lake basins on the Southern High Plains of West Texas. Spacial distribution of soils, plants, and time-space distribution of soil moisture and ponded storage volume were to be correlated, if possible, with absorbance-reflectance date supplied by ERTS-1 imagery.

B. METHODOLOGY

Three lake basins, similar to the tens of thousands on the Southern High Plains, were originally investigated for this study; however, receipt of initial imagery showed the basins too small for measurement of water fluctuations. A fourth, but much larger test site, was then designated.

NASA-furnished ERTS-1 imagery was studied by both optical and electronic methods, the film data later being compared to digitized data from computer tapes.

C. CONCLUSIONS

Although recognizable from ERTS-1 imagery, detailed water fluctuations in small playa lake basins of less than 12.141 sq. m. cannot be accurately monitored. However, a dual, playa complex approximately 8.0 km. long was large enough for MSS imagery resolution to allow measurement of water fluctuation. Resultant water fluctuations in one of the playas of the fourth test site were correlated with water depth; however, the 18-day cycle was too long for the monitoring of typical playa-type (very shallow) lakes.

Of the MSS imagery, Band 5 is most usable in semi-arid West Texas, having the highest overall contrast. Definition of Band 4 is less due to reduced tonal contrast. The greatest local contrast between dry land and water areas occurs on Bands 6 and 7, Band 6 being particularly good for defining large water areas. Band 7 is best for definition of small water areas and Band 5 is best for defining growing vegetation.

MSS imagery was used to provide the first regional census of the small water-filled lake basins of West Texas and eastern New Mexico. A cost/benefit analysis comparing the use of ERTS-1 data to more conventionally secured data, shows that the use of ERTS-1 data for such a census resulted in a cost reduction of from $2.00 to $0.03 square mile.

ERTS-1 imagery was also used to trace the surface moisture paths of local storm cells.

SECTION I

DYNAMICS OF PLAYA LAKES IN THE TEXAS HIGH PLAINS

INTRODUCTION

A. PURPOSE

The purpose of this report is to document the activity history of NASA contract NAS-5-21720. This contract was awarded to W.D. Miller, Principal Investigator, in April, 1972, to initiate proposal 342-C of the ERTS-1 data-user investigation program.

B. OBJECTIVES AND PERSONNEL

Objectives were to correlate ERTS-1 imagery with the water balance ecosystem and geology/ morphology of select playa lake basins in West Texas by study of time-space relationships of precipitation, runoff, infiltration, evapo-transpiration, and geology of the basins. Accordingly, a multidisciplinary team was assembled, which included the following members and specialties:

Dr. W.D. Miller - Hydrology, Department of Geosciences, Texas Tech University, Lubbock, Texas.

Dr. C.C. Reeves, Jr. - Geology, Department of Geosciences, Texas Tech University, Lubbock, Texas.

Dr. B.L. Allen - Soils, Department of Agronomy, Texas Tech University, Lubbock Texas.

Dr. R. Meyer - Soil Moisture, Department of Agronomy, Texas Tech University, Lubbock, Texas

Dr. D.R. Haragan - Meteorology, Department of Geosciences, Texas Tech University, Lubbock, Texas

Dr. T.E.A. van Hylckama - Hydrology, U.S. Geological Survey, Lubbock, Texas.

Dr. D.M. Wells - Civil Engineering, Water Resources Center, Texas Tech University, Lubbock, Texas.

Dr. B.J. Claborn - Civil Engineering, Department of Civil Engineering, Texas Tech University, Lubbock, Texas.

Dr. J.W. Hawley - Geology-Soils, Soil Conservation Service, Tech Tech University, Lubbock, Texas.

Although the director of the project and the compiler of this report was C.C. Reeves, Jr., the following major categories were the responsibility of the listed individuals:

Geology - C.C. Reeves, Jr.
J.W. Hawley
J.W. Buchanan, Jr. (Master's candidate)

Hydrology - B.J. Claborn
T.E.A. van Hylckama
C.C. Reeves, Jr.

Meteorology - D.R. Haragan

Soils - B.L. Allen
J.E. Goebel (Doctorate candidate)

During the course of the project Dr. Meyers took an extended leave, thus soil moisture determinations were calculated by Dr. R.G. Stevens and Mr. Brian Fish (Master's candidate).

C. BACKGROUND FOR THE INVESTIGATION

The agricultural economy of the Southern High Plains, Texas and New Mexico, is unusually dependent on irrigation water derived from the Pliocene Ogallala Formation. Over 5 million irrigated acres, located mainly in West Texas, produce approximately 25 percent of the cotton and 33 percent of the grain sorghum grown in the United States, thus the declining water level in the Ogallala aquifer is a problem of national significance. Solutions to this impending problem, ranging from salvage of water periodically stored in ubiquitous playa lake basins to importation of water from Canada to the southern United States, have been studied by the U.S. Geological Survey, U.S. Bureau of Reclamation, U.S. Corps of Engineers, the Texas Water Development Board, and personnel of Texas Tech University.

Part of the so-called Texas Water Plan (Texas Water Development Board, 1968), calls for the delivery of 8.5 million acre-feet of fresh water to the West Texas area. The water, taken from excess flow in the lower Mississippi River, would be lifted approximately 2700 feet by a 700-mile canal for local distribution on the Southern High Plains of West Texas and eastern New Mexico. In 1973 the total cost of such a project was projected at $20,493,000,000, with an annual economic cost of $1,914,600,000. Annual primary benefits to annual economic cost are in the ratio of 0.14 to 1.0. The Texas Water Plan was therefore considered economically infeasible by the U.S. Bureau of Reclamation (1973).

Unquestionably a major source of fresh water for both surface and natural and artificial recharge intermittedly exists in the thousands of playa lakes common to the Southern High Plains. Such basins, which range in size from about 4000 sq. m. to over 2,000,000 sq. mo., have an average density of about 1 per 1.161 km. After rainstorms, and during wet years, runoff collects on the lake bottoms, but in most instances is subsequently lost by evaporation. Locally some of the playa lake water may infiltrate and some is utilized for supplemental irrigation, but no serious regional efforts have been made to salvage the available lake water. Unfortunately little is known of the hydrologic budget of the small playa lake basins although the quantity of the lake water has proven to be acceptable (Riekers and others, 1970; Wells and others, 1970).

With this knowledge in mind Dr. W.D. Miller and the writer prepared a proposal dealing with correlation of ERTS-1 satellite imagery with hydrologic parameters of the West Texas lake basins, and were subsequently awarded a contract for participation in the NASA-ERTS Mission Program. Figure 1 illustrates the location of study area and the locations of individual study sites.

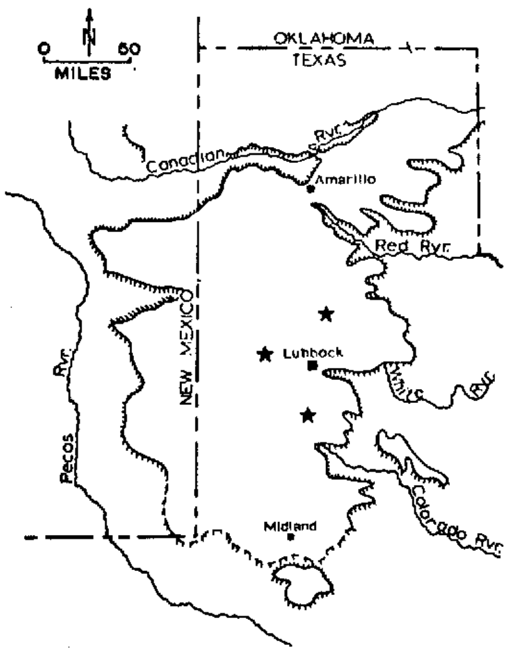


Figure 1 - Index map of the Southern High Plains. The hachured line represents the escarpment defining the High Plains. The stars designate the local ERTS-1 study sites.

D. STUDY SITES

During the spring of 1972 three ERTS-1 study sites, typical of the tens of thousands of similar lake basins which pock-mark the Southern High Plains, were selected in the Lubbock area. Site No. 1, termed the Heard Playa, was located 0.65 miles east of the intersection of FM roads 37 and 400, appearing on the Julia Lake 7 1/2' Quadrangle, Hale County, Texas, at approximately 33°58'30"N, 101°39'30"W. This site was east-northeast of Lubbock (Fig. 1).

Study site No. 2, termed Spade Ranch Playa, was located two miles west of FM 168 and four miles north of State Highway 116, appearing on sheet 34 of the Hockley County Soil Survey (1961 Series, No. 27) at approximately 33°38'N, 102°14'W. This site is west of Lubbock (Fig. 1). Site No. 3, termed the T-Bar Playa (Fig. 2), was located 4.6 miles west of Tahoka, Texas, and one mile south of U.S. Highway 380, appearing on the Double Lakes 7 1/2' Quadrangle at approximately 33°09'N, 101°53'30"W. This site is south of Lubbock (Fig. 1).

Field work was initiated at the study sites on May 9, 1972, field studies being supervised by Co-investigator C.C. Reeves, Jr. However, on June 22, 1972, the Principal Investigator (W.D. Miller) was killed in a plane crash, thus Reeves assumed the role of Principal Investigator for the remainder of the project.

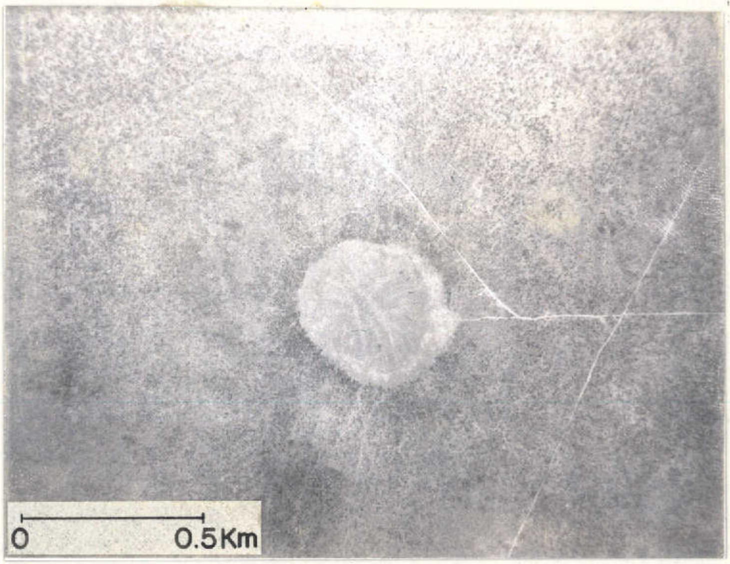


Figure 2 - Study site No. 3, T-Bar playa, Lynn County, Texas (from CRH-2KK-226, February 27, 1969).

SECTION II

STUDY METHODS/RATIONALE

A. STUDY SITES

Prior to the first overpass of the ERTS-1 satellite the three test sites were surveyed and staked on a 100 m. grid. The morphology of each basin, with respect to surrounding eolian units, and the thickness of lacustrine fill within each basin, was then determined by power auger and drill holes. A complete soil survey was conducted at each test site by power probe or post-hole auger holes on the 100 m. grid.

The T-Bar and Heard playas were instrumented with water level recorders, infiltrometers, tensiometers, Class A evaporation pans, totalizing aneometers, weighing rain gauges and continuous recording microbarographs and hygro-thermographs (Fig. 3) to provide a record of the water budget of the site. Most of the equipment was supplied by Texas Tech University although use of the power auger and power probe were contributed by the Soil Survey Investigations Unit, SRTSC, Soil Conservation Service, Department of Agriculture.

Because of the indicated theoretical resolution limit of ERTS-1 imagery, and the size of the test sites, it was suspected that monitoring of water fluctuations would be impossible. Therefore, an additional test site representative of the large type saline playa basins found in the semi-arid and desert areas of the world, was selected. This site, known as Double Lakes (Fig. 4), is located on the Double Lakes, Texas, 7 1/2 ' Quadrangle. Double Lakes consists of a dual playa complex about 8046 m. long in a basin of approximately 15.0 sq. km., located approximately 8 km. northwest of the original T-Bar study site: both sites are south of Lubbock (Fig. 1). After receipt of initial imagery, which confirmed that the first three study sites were not large enough to be workable, the Double Lakes test site was instrumented and the three small study sites abandoned, although weather data from the T-Bar playa was accumulated due to its proximity to the principal test site. Measurements of water fluctuations and correlation with water depth was conducted on the

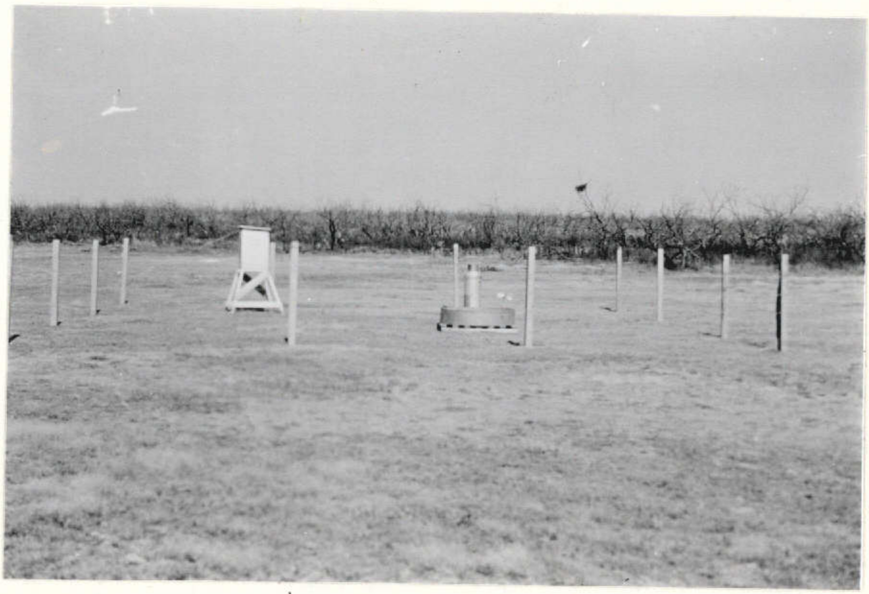


Figure 3 - Weather station at T-Bar playa test site, Lynn County, Texas. View to the northwest.

Figure 4 - The northern playa of the Double Lakes study site, Lynn County, Texas. View from the northeast to the southwest. The edge of the southern playa appears in the background and the arrow marks the location of the weather station. The star marks the location of neutron probe #1.

north playa only of the Double Lakes complex.

B. METHODS OF ANALYSIS

Imagery from all four of the ERTS-1 MSS bands was received in 70 mm and 9 x 9-inch transparency format, and color composites were ordered later. The test sites were then located on the transparencies and studied by using a B and L zoom stereoscope. In some cases both positive and negative prints were locally made of select frames and enlargements of select frames were ordered from the EROS Data Center.

ERTS-1 scenes from Bands 5 and 7 of the MSS, covering the period 29 July 1972 through 24 July 1973, were analyzed at Stanford Research Institute by using the ESIAC. The electron console was used to measure the areas of the Double Lakes playas, the areas of the playas covered by water, and to enhance the spectral signatures of the three small test sites.

A visual count of the number of filled lake basins on frame 1078-16526-7 and a total count of water-filled lake basins on the Southern High Plains, from a mosaic of images taken during the Fall of 1972, were also make by SRI personnel.

C. IMAGERY

The ERTS-1 satellite, launched July 23, 1972, first passed over the West Texas study sites on July 29, 1972. Table 1 summarizes the ERTS-1 passes over the study sites, listing the bands received, condition of the sky and the image quality.

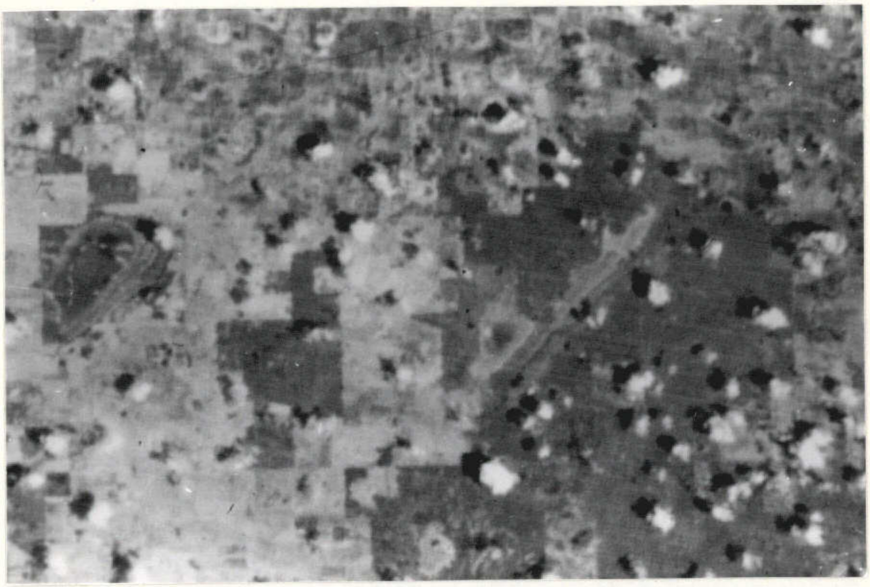
During the period (July 1972-August 1973) when monitoring of the test site(s) occurred, only 52 percent (11 out of 21) of the ERTS-1 passes were useful due to an unusually high incidence of stormy weather. The sequence of enlargements of usable ERTS-1 passes (MSS Bands 5 and 7) are shown by the sequence of Figures 5 through 16. Comparison of the relative sizes of the T-Bar and Double Lakes test sites by referring to Figure 2 and then to the ERTS-1 imagery enlargements will illustrate why the first three study sites were abandoned.

TABLE 1 - SUMMARY OF ERTS-1 PASSES OVER THE TEST AREAS
DURING PERIOD JULY, 1972-SEPTEMBER 1, 1973

DATE	BANDS	ORBIT-SCENE	SKY CONDITION	QUALITY	COLOR COMPOSITES AVAILABLE	REMARKS
July 29	4,5,6	1006-16522	20% clouds	Fair	No	Electronic noise
Aug 16	4,5,6,7	1024-16522	30% clouds	Good	Yes	Clouds in test areas
Sept 3	----	-----	Overcast	----	---	------------
21	----	-----	Overcast	----	---	------------
Oct 9	4,5,6,7	1078-16524	10% clouds	Good	Yes	Clouds north of test site
27	----	-----	Overcast	----	---	------------
Nov 14	4,5,6,6	114-16532	10% clouds	Good	Yes	Clouds in SE corner
Dec 2	4,5,6,7	1132-16532	0% clouds	Good	Yes	------------
20	----	-----	Overcast	----	---	------------
Jan 7	----	-----	Overcast	----	---	------------
25	----	-----	Overcast	----	---	------------
Feb 12	4,5,6,7	1204-16533	0% clouds	Good	Yes	------------
Mar 2	----	-----	Overcast	----	---	------------
20	4,5,6,7	1240-16534	5-% clouds	Good	Yes	Clouds southern half, site clear

DATE	BANDS	ORBIT-SCENE	SKY CONDITION	QUALITY	COLOR COMPOSITES AVAILABLE	REMARKS
Apr 7	4,5,6,7	1258-16534	0% clouds	Good	Yes	------------
25	----	-----	Overcast	----	---	------------
May 13	----	-----	Overcast	----	---	------------
31	----	-----	Overcast	----	---	------------
June 18	4,5,7	1330-16531	0% clouds	Good		Band 6 missing
July 6	4,5,6,7	1348-16525	0% clouds	Good	Yes	
24		1366-16524				
Aug 11	4,5,6,6	1384-16523		Good	Yes	
29	----	-----	Overcast	----	---	------------

Figure 5 - The 29 July 1972 pass (1006-16522) of the Double Lakes and T-Bar test sites, Lynn County, Texas. Band 7 not available. White dots on lower part of picture are electronic noise. The arrow marks the T-Bar site: The dual arrows the Double Lakes site.



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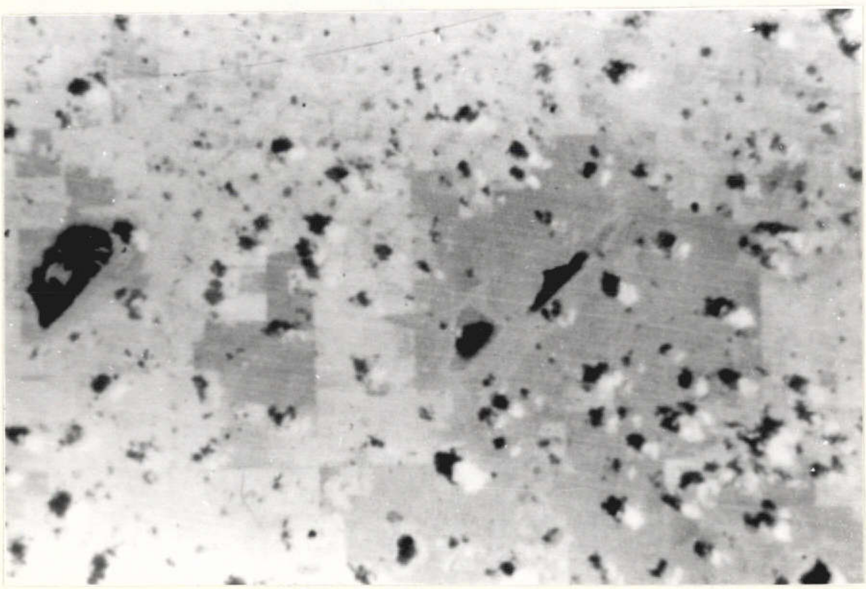
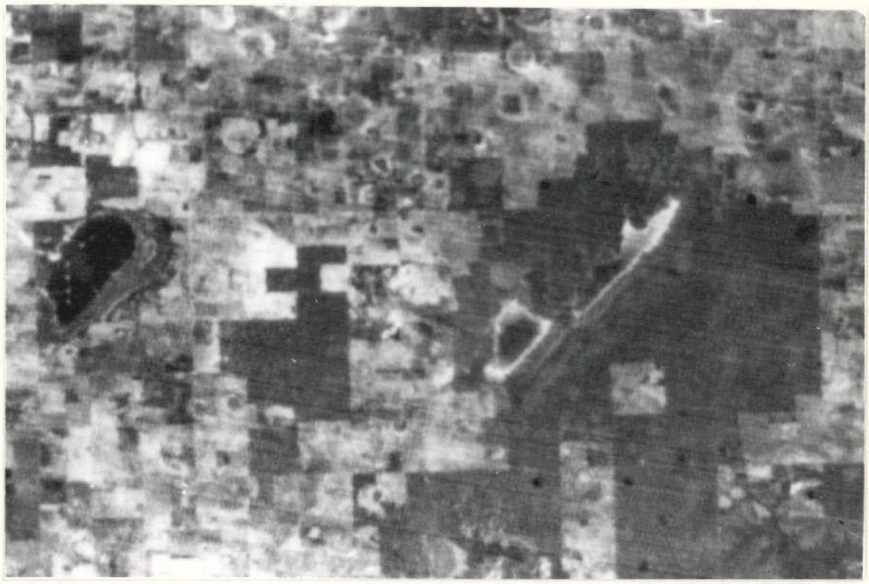


Band 7

Figure 6 - The 16 August 1972 pass (1024-16522) of the Double Lakes and T-Bar test sites, Lynn County, Texas.



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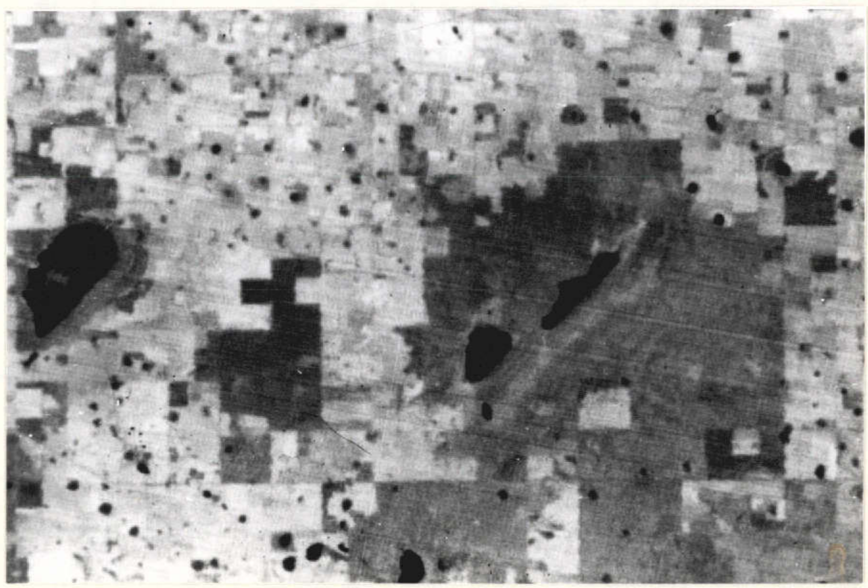
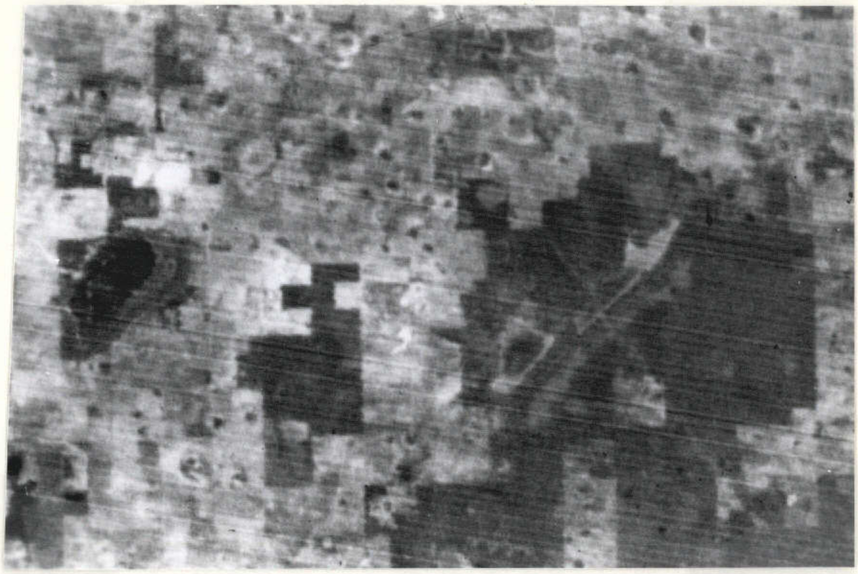


Band 7

Figure 7 - The 9 October 1972 pass (1078-16524) of the Double Lakes and T-Bar test sites, Lynn County, Texas.



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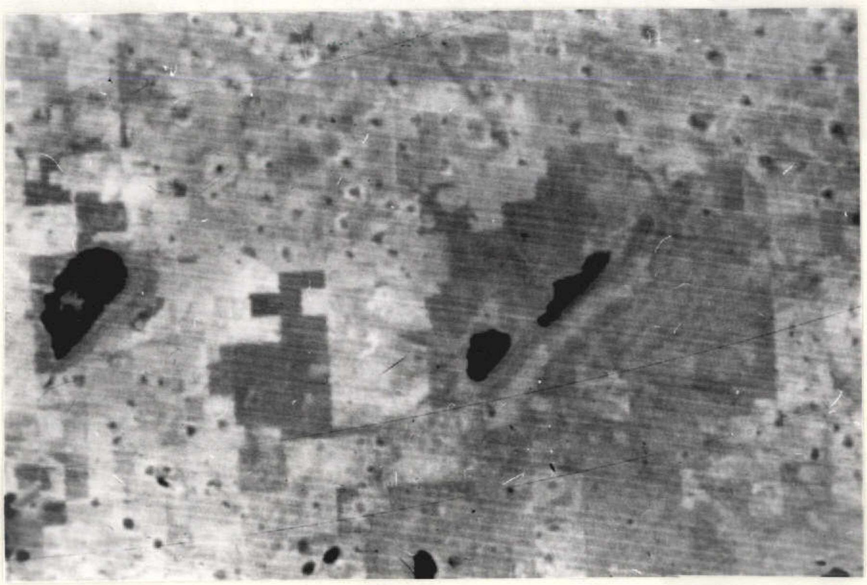
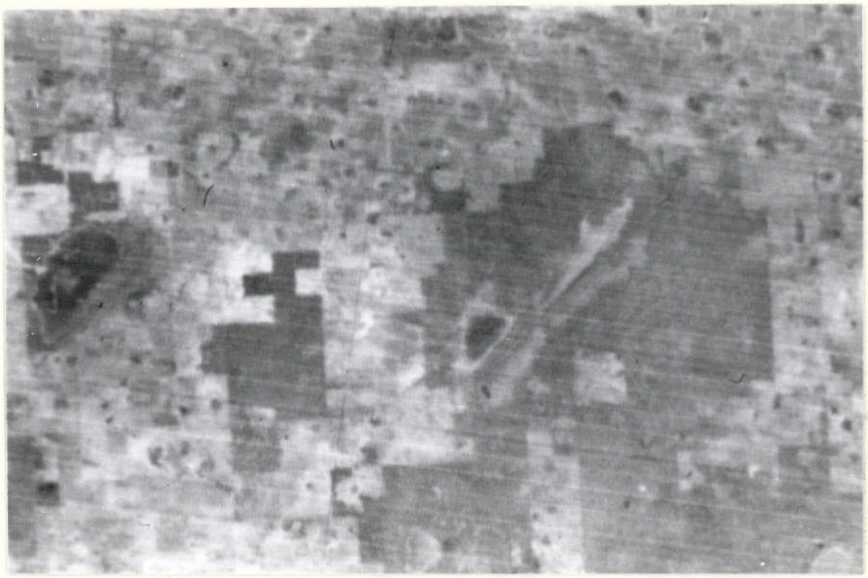


Band 7

Figure 8 - The November 1972 pass (1114-16532) of the Double Lakes and T-Bar test sites, Lynn County, Texas.



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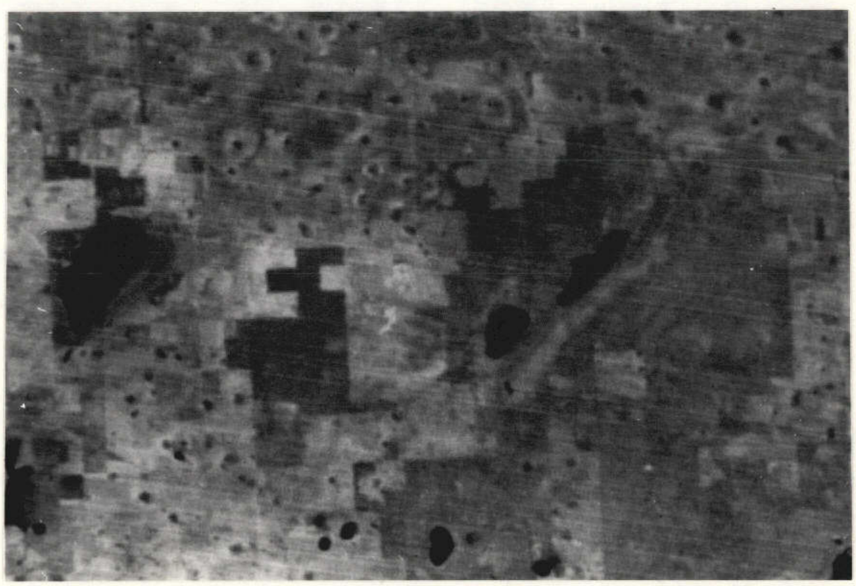


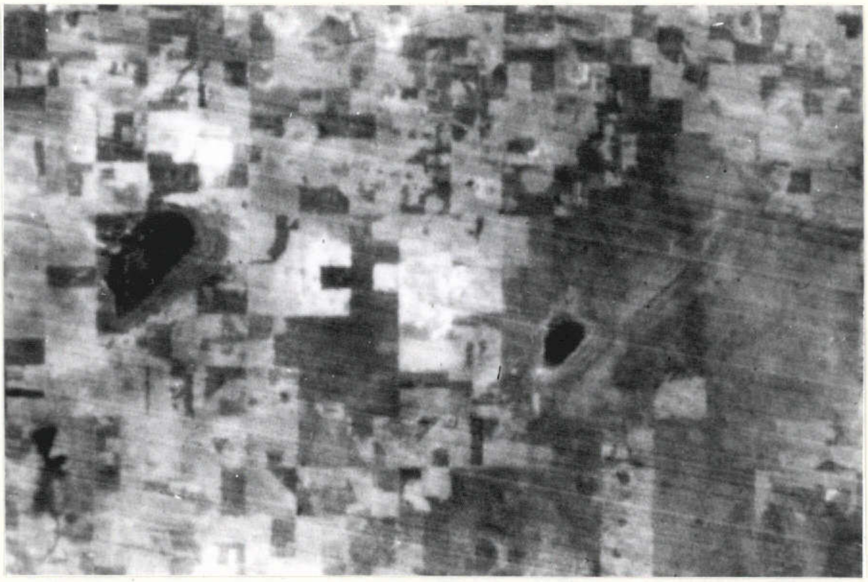
Band 7

Figure 9 - The 2 December 1972 pass (1132-16532) of the Double Lakes and T-Bar test sites, Lynn County, Texas.

Band 5

Band 7

Figure 10 - The 12 February 1973 pass (1204-16533) of the Double Lakes and T-Bar test sites, Lynn County, Texas.



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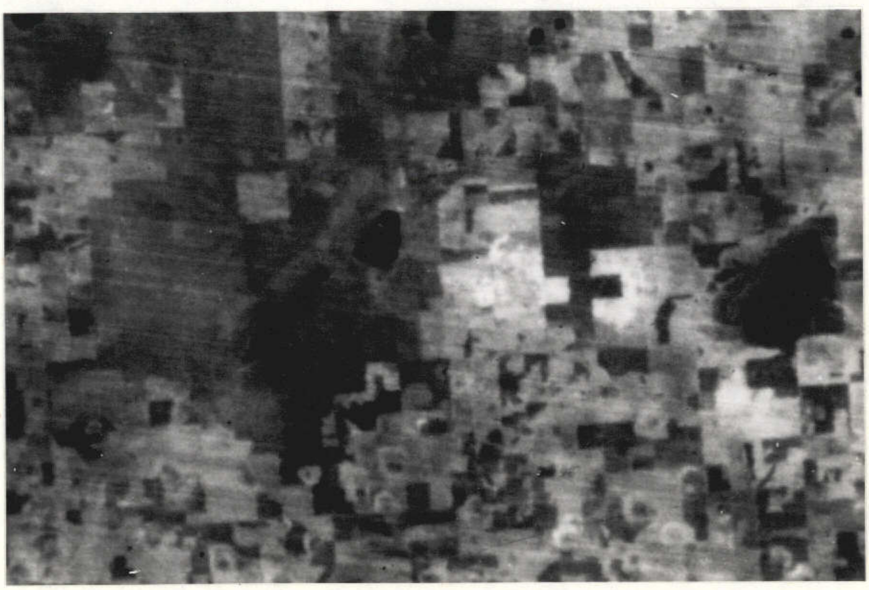
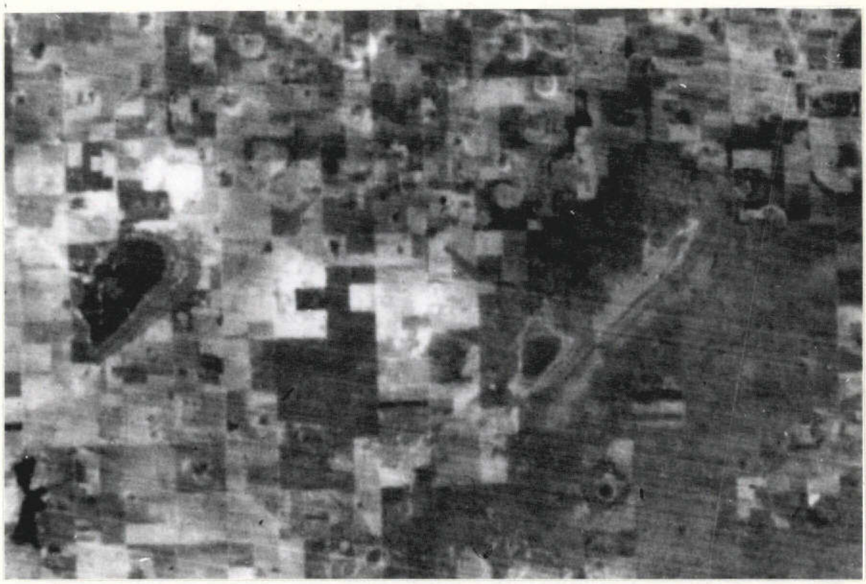


Band 7

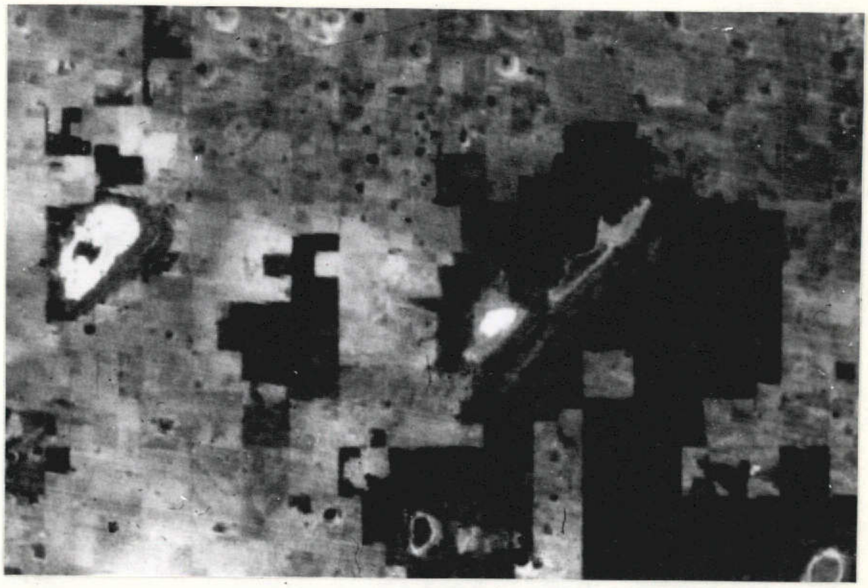
Figure 11 - The 20 March 1973 pass (1240-16534) of the Double Lakes and T-Bar test sites, Lynn County, Texas.



Band 5

Band 7

Figure 12 - The 7 April 1973 pass (1258-16534) of the Double Lakes and T-Bar test sites, Lynn County, Texas.



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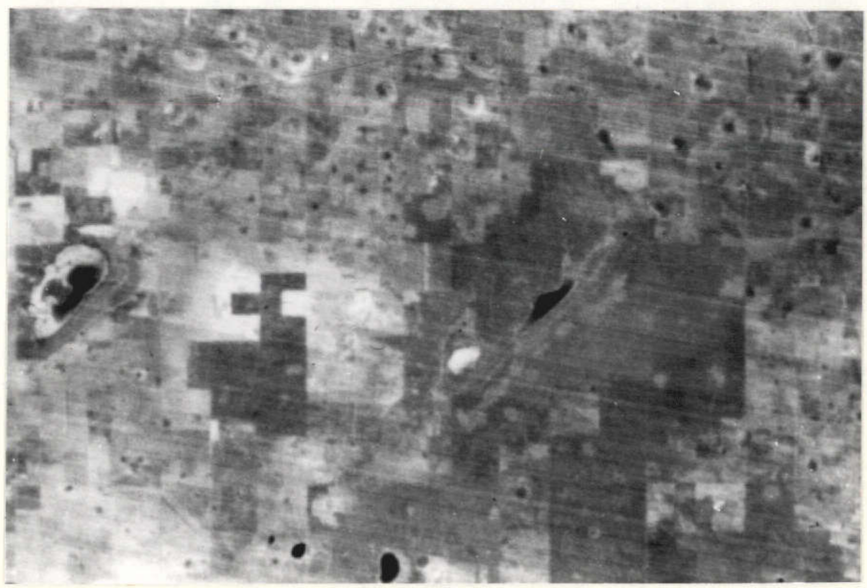

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Figure 13 - The 18 June 1973 pass (1330-16531) of the Double Lakes and T-Bar test sites, Lynn County, Texas.

Band 5

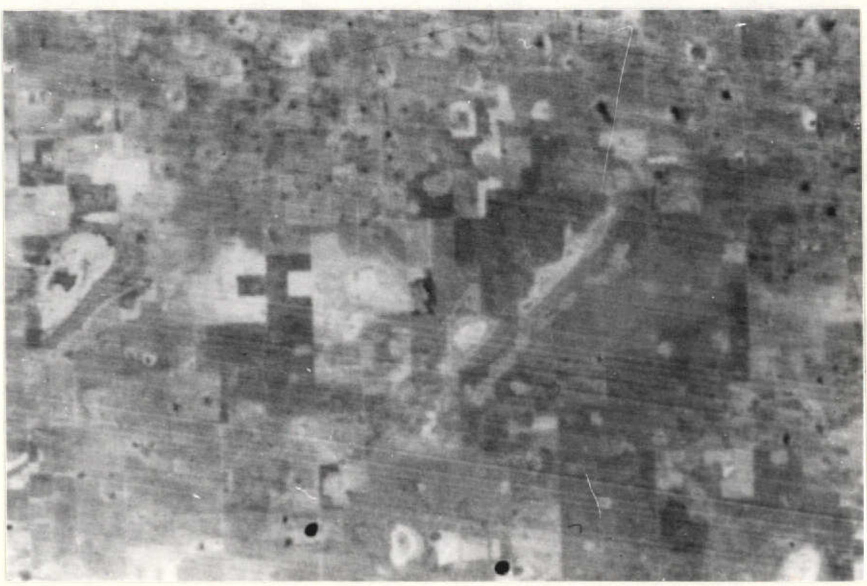

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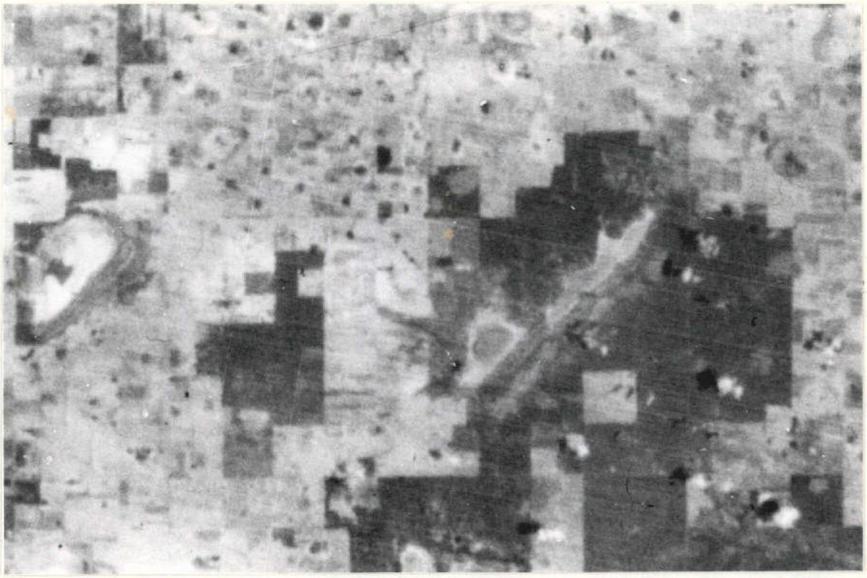
Figure 14 - The 6 July 1973 pass (1348-16525) of the Double Lakes and T-Bar test sites, Lynn County, Texas.



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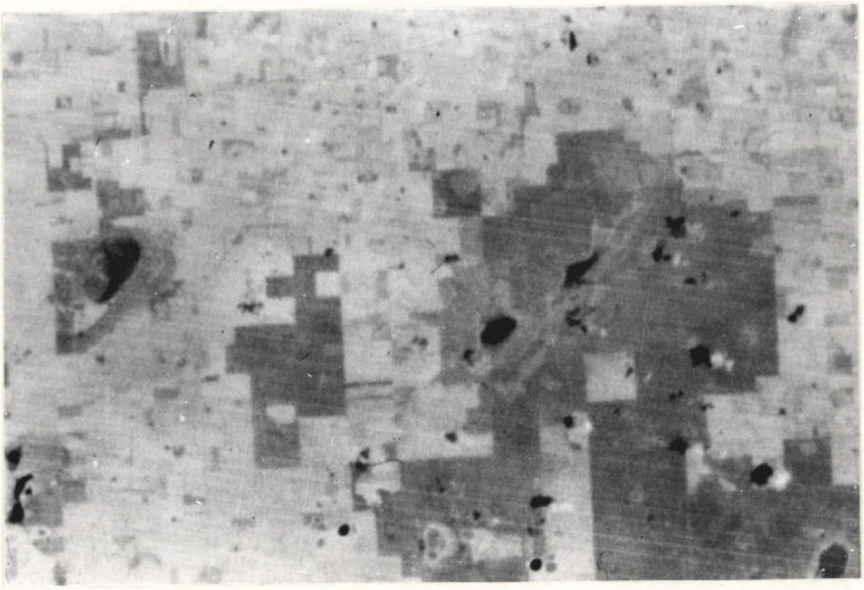
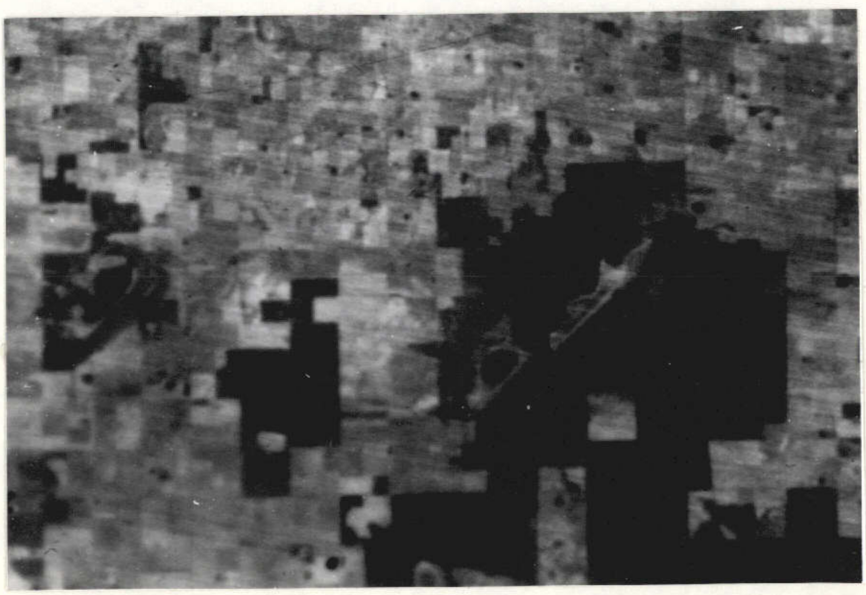


Band 7

Figure 15 - The 24 July 1973 pass (1366-16524) of the Double Lakes and T-Bar test sites, Lynn County, Texas.

Band 5



Band 7

Figure 16 - The 11 August 1973 pass (1384-16523) of the Double Lakes and T-Bar test sites, Lynn County, Texas.

SECTION III

RESULTS OF THE INVESTIGATION

Table 2 summarizes the principal characteristics of the Double Lakes test site. The Double Lakes site is located on the T-Bar Ranch which is owned by the Cass Edwards Estate, Ft. Worth, Texas. Much of the 56 sq. km. drainage basin was at one time covered by a shallower though much larger closed lake, thus soils surrounding the present Double Lakes playas have formed on saline lacustrine sediments. The saline soils and the absence of potable ground water in most of the Double Lakes basin prevents cultivation: most of the area is used for grazing.

A. SOILS

The soils in the Double Lakes area consist of the Amarillo, Arvana, Brownfield, Drake, Portales, Potter, Randall, Tivoli and Zita. Table 3 summarizes the principal characteristics of these soils and Table 4 illustrates the classification and competing soils series used in this project. The published Lynn County Soil Survey (Mowery and McKee, 1953) was used as a base for the soils map of the Double Lakes area (Fig. 17). Morphology of the soil units at the Double Lakes test is listed in Appendix A.

There is a remarkable correlation between geologic units and soils in the Double Lakes basin. For example, the Drake soil has formed on debris deflated from the playas during Recent time, the Portales and Zita on outcrops of the Wisconsin Tahoka clay, the Potter over outcrops on the "caprock" caliche (Pliocene), the Amarillo and Brownfield soils on Illinoian "cover sands", and the Tivoli represents present active sand areas (compare Figs. 17 and 20).

Wide variations exist in the permeability and moisture-holding capacities of the soils in the test site area. Appendix G illustrates data secured from the neutron probes placed at the Double Lakes and nearby T-Bar playa test sites. Soil moisture as percent by volume was computed at depths of 15, 5, 30.5, 59.5, 91.0, 120.0, and 155.0 cm., as well as total inches in the soil profile.

TABLE 2 - PRINCIPAL CHARACTERISTICS OF THE DOUBLE LAKES TEST SITE, LYNN COUNTY, TEXAS

CHARACTERISTICS	SIZE
Greatest surface diameter	
North playa	1.12 km.
South playa	1.44 km.
Length:	
North playa	4.70 km.
South playa	2.32 km.
Playa area:	3.00 sq. km.
North playa	
South playa	
Area drainage basin:	56 sq. km.
Lacustrine fill thickness:	
Present playas	> 6 m.
Total	>18 m.
Generations of fill:	3 or more
Main playa soil:	Randall
Main basin soil:	Portales and Drake
Petrocalcic "basement":	No
Associated dune(s):	Yes
Location	Southeast
Playa shapes	
North playa	Linear
South playa	Subangular
Probable origin:	Blocked drainage channel

TABLE 3 - CHARACTERISTICS OF THE SOILS
WHICH OCCUR IN THE TEST SITE AREAS
AND SYMBOLS USED ON THE SOIL MAP

SOIL	SLOPE	SYMBOLS
Amarillo	--	A
Brownfield	--	Br
Drake	0-1%	Dr
Mansker	1-3%	M
Portales	0-2%	Pb
Potter	--	Pe
Randall	0-1%	R
Tivoli	--	T
Zita	0-1%	Z

TABLE 4 - CLASSIFICATION OF SOIL SERIES AND COMPETING SOILS SERIES USED IN THIS STUDY

SOIL	CLASSIFICATION
Amarillo	Aridic Paleustalfs Fine-Loamy, Mixed, Thermic
Brownfield	Arenic Aridic Paleustalfs Loamy, Mixed, Thermic
Drake	Typic Ustorthents Fine-Loamy, Mixed (calcareous), Thermic
Mansker	Calciorthidic Paleustolls Fine-Loamy, Carbonatic, Thermic
Portales	Typic Calciustoll Loamy, Mixed, Thermic
Potter	Ustollic Calciorthids Loamy, Carbonatic, Thermic, Shallow
Randall	Uldic Pellusterts Fine, Montmorillonitic, Thermic
Tivoli	Calciorthidic Paleustalfs Fine-Loamy, Carbonatic, Thermic
Zita	Aridic Haplustolls Fine-Loamy, Mixed, Thermic

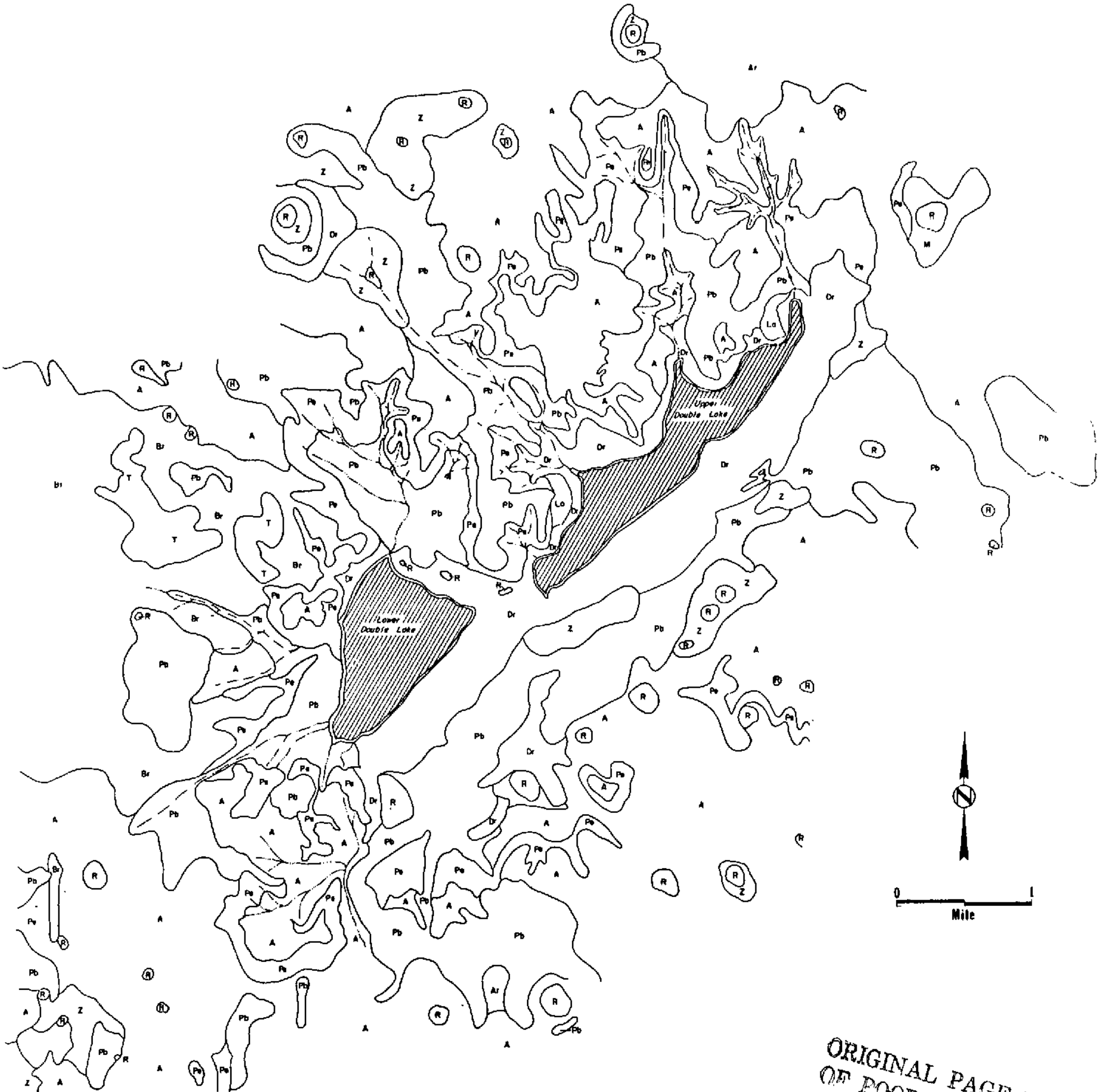


Figure 17 - Soils map for Double Lakes test site, Lynn County, Texas.

B. GEOLOGY

A total of 33 power auger and drill holes (Appendix B) totaling 360 m. and a 23 m. core hole (Appendix C) were placed in the Double Lakes test area. The locations of the auger, drill and core holes at the test site are shown on Figure 18.

1. Morphology

The Double Lakes drainage basin covers approximately 56 sq. km. with the two playas covering about 3.0 sq. km. Subsurface data shows that the basin is a long, narrow, linear depression in the Cretaceous (Commanche Series) Duck Creek and Kiamichi Formations (Fig. 19) bounded on the west by three buried Cretaceous topographic highs. The depression leads into a narrow channel to the northeast which may have been a tributary to the larger Slaton Channel in the northern part of the country.

2. Stratigraphy

a. Cretaceous

The geologic map (Fig. 20) illustrates the stratigraphic units in the Double Lakes test site area. The Kiamichi Formation is the oldest unit exposed along the western side of the basin, although nearby well logs indicate that the Kiamichi Formation is underlain by the Edwards Formation and other formations in the Fredericksburg and Trinity Group. The Cretaceous section is approximately 83 m. thick in the Double Lakes area, but only the upper 3.6 to 4.8 of the section is exposed.

Cretaceous rocks underlie the entire Double Lakes area, partially forming an escarpment marking the western edge of the present playas. The Cretaceous rocks exposed on the western edges of the two playas consist of the Duck Creek (Washita Group) and Kiamichi (Fredericksburg Group) formations, both of which are members of the Comanche Series. Brand (1953) describes the Kiamichi Formation as a dark gray to moderate yellowish-brown limestone and moderate yellowish-brown to dark gray shale and thin gray to brown limestone and sandstone. The exact thickness of the Kiamichi Formation in the Double Lakes basin area is unknown, although a well log in section 230

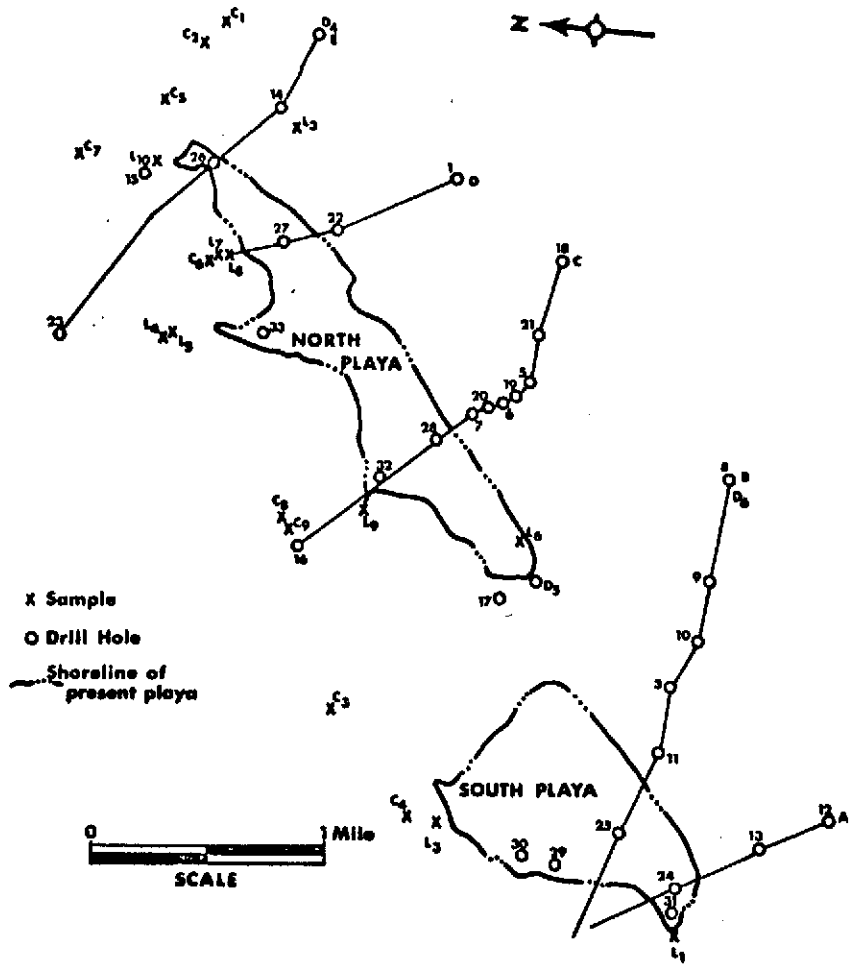


Figure 18 - Plat of the Double Lakes test site illustrating locations of power auger and drill holes.

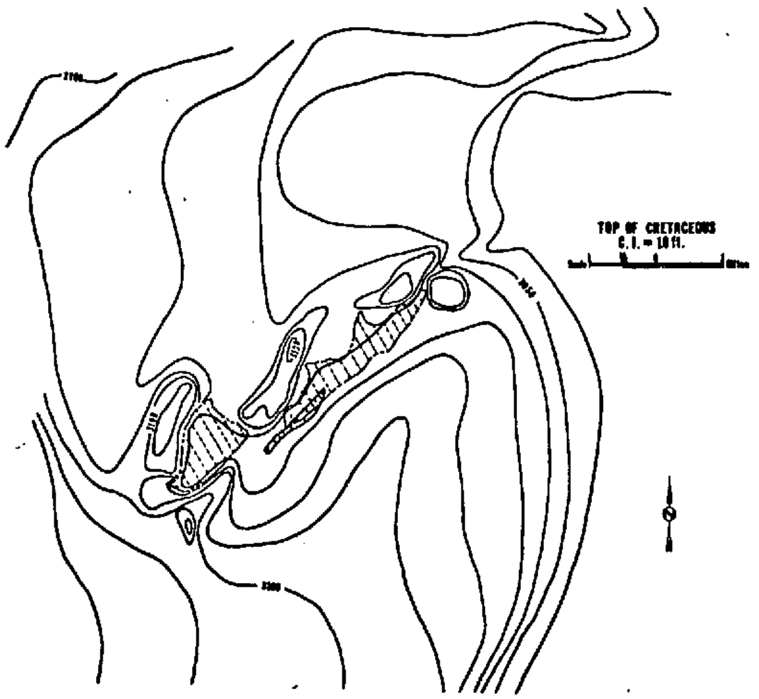


Figure 19 - Map on top of the Cretaceous (Duck Creek and Kiamichi Formations) at the Double Lakes test site, Lynn County, Texas.

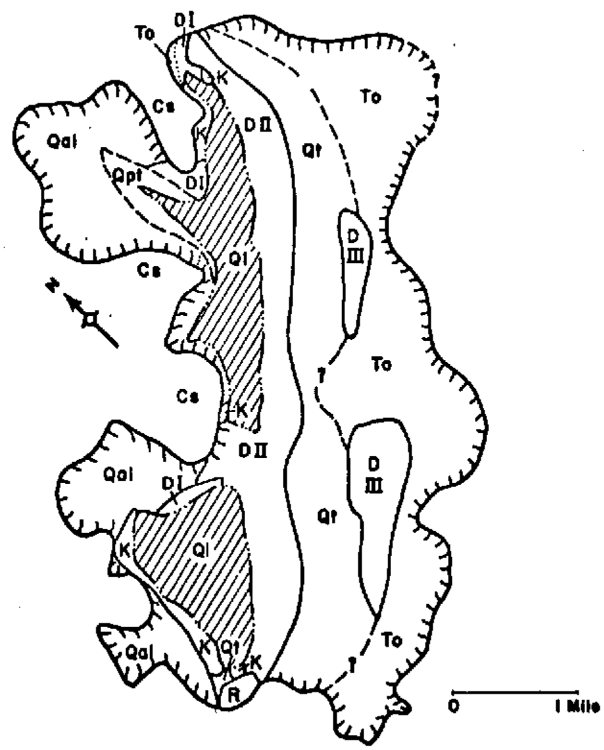


Figure 20 - Geologic map of the Double Lakes test site, Lynn County, Texas. R = Tivoli sands, Qal = Quaternary alluvium, Ql = Quaternary lacustrine, Qt = Quaternary Tahoka Formation, Qpt = pre-Tahoka sediments, D_I, D_{II}, D_{III} = Drake dunes, Cs = "cover sands", K = Cretaceous

of the EL and RR survey (Texas Water Development Board) 3.3 km. west of the basin indicates a thickness of approximately 59 m. The Duck Creek Formation ranges from 1.8 to 3.5 m. in thickness in drill holes and outcrops in the Double Lakes area.

The contact between the Kiamichi Formation and the overlying Duck Creek Formation is often difficult to distinguish in drill holes and outcrops, although the Kiamichi Formation has a Munsell solor of dark olive green (2.5GY) to yellowish-brown (2.5Y) and the Duck Creek Formation is yellowish-brown (2.5Y). However, Brand (1953) gives the following criteria (other than fauna):

> "The upper Kiamichi Formation consists typically of medium gray to black shale with interbeds of modular, argillaceous, unfossiliferous limestone. The basal Duck Creek Formation consists of moderate yellow to gray shale with interbeds of brown, thinly-bedded, fossiliferous limestone."

The Kiamichi Formation outcrops along the western edge of the present playas and underlies Pleistocene and Tertiary sediments on the east side of the basin. The Duck Creek Formation is absent beneath most of the present playas where the Kiamichi Formation is directly overlain by Pleistocene lacustrine sediments.

b. Tertiary

Tertiary sediments in the Double Lakes basin are represented by the Pliocene Ogallala Group. Evans (1949) suggested raising the Ogallala Formation to Group rank by dividing the Ogallala into the upper Bridwell Formation and the lower Couch Formation. In the type area along the eastern escarpment of the Southern High Plains the Couch Formation, representing valley alliviation, is mainly pinkish-gray, well-sorted, calcareous sand, with basal gravel (Evans, 1949). The Bridwell Formation consist mainly of unconsolidated, reddish-brown sands and clays, with occasional thick, channel gravels (Evans, 1949). On outcrop, the Couch Formation exhibits a 10YR Munsell color, whereas the Bridwell Formation is usually 7.5YR or slightly redder.

In the Double Lakes area the Ogallala Group consists of 6.0to 21.0 m. of sands and sandy clays of

2.5YR to 2.5Y hues. The 2.5Y and 5YR, along with 7.5YR and 10YR hues occur on the east side of the basin where the Ogallala is covered by Pleistocene lacustrine deposits. The 7.5YR and 10YR colored sands, however, occur with the 2.5YR and 5YR in the upper part of the Ogallala section along the western side of the basin.

Mineralogically, the Ogallala Group sands consist predominately of sub- to well-rounded quartz grains with minor amounts of chert and feldspar. The predominant clay mineral in the Ogallala sands is smectite with minor amounts of illite and kaolinite being present (Parry and Reeves, 1968).

The circumference of the Double Lakes basin is marked, in most areas, by the Ogallala "caprock" caliche. Mineralogically, the "caprock" is comprised primarily of calcium carbonate, with minor amounts of quartzose sand, dolomite, clay, microcrystalline quartz, chalcedony, and dolomite. Clay minerals reported in the "caprock" caliche of the Llano Estacado are primarily illite, smectite and kaolinite (Aristarain, 1970; Parry and Reeves, 1968). In outcrop, observed thickness of the "caprock" caliche in the test site area is from 4 to 8 feet.

c. Quaternary

Quaternary strata in the Double Lakes basin overlies the Ogallala "caprock" caliche, Ogallala sands, or the Cretaceous formations. The Quaternary sediments deposited on the Southern High Plains of West Texas and eastern New Mexico are eolian, lacustrine, and fluvial in origin, but nevertheless have been successfully correlated with Pleistocene glacial sequences in central and western Kansas and Nebraska by Frye and Leonard (1957b: 1965).

Early Pleistocene sediments on the Southern High Plains are represented by the Blanco (Nebraskan) and Tule (Kansan) formations. Both formations consist mainly of lacustrine sands and clays. The Blanco type locality is in Blanco Canyon 88 km. northeast of Double Lakes and the type locality of the Tule Formation is about 160 km. northeast of Double Lakes in western Briscoe County. No stratigraphic evidence of early Pleistocene (Nebraskan or Kansan) sedimentation in the Double Lakes basin was found; however, 12.8 km. to the southeast, in the Guthrie Lake basin, there is an outcrop of Pleistocene volcanic ash. Izett, Wilcox, and Borchardt (1972) found that the youngest volcanic ash on the Southern High Plains is at least 600,000 years old (Pearlette type-O) and the oldest (Pearlette-B) about 200 million years. Pearlette-O is interbedded with lake deposits (Tule Formation) to the north of the test site (Schultz, 1972), therefore, Guthrie basin could be as old as 2.0 million years.

Deposits of mid-Pleistocene age found on the Southern High Plains are represented by the "Illinoian cover sands" (Frye and Leonard, 1957b). Reeves (1970) found no lacustrine sediments of Illinoian age on the Southern High Plains, but suggested that such sediments probably exist beneath present playa fills.

Evans and Meade (1945) used the term "Tahoka Clay" for the late Pleistocene (Wisconsin) lacustrine deposits on the Southern High Plains of West Texas, the type area being Tahoka Lake 19 km. to the east of Double Lakes. Oldfield and Schoenwetter (1964) from pollen evidence, restricted the Tahoka interval in West Texas to the time period 20,000 to 14,000 years B.P., but Reeves (1970) correlated the Tahoka interval with the Woodfordian glacial period which occurred during the period 22,000 to 12,500 years B.P. in the northern glacial areas.

During Tahoka time the Vigo Park Dolomite was deposited, the regional continuity of which was discussed by Reeves (1970). On the basis of the widespread period of desiccation suggested by the Vigo Park Dolomite, Reeves (1970) proposed the division of the Tahoka Formation into the upper Brownfield Lake Member and the lower Rich Lake Member, the type areas being Brownfield Lake and Rich Lake (Terry County), respectively. The Brownfield Lake Member is described as a yellowish-gray (5Y 7/2 to 8/1) clay with lenses of sand (5Y 7/2) grading upward into a light gray (N8) sand, and the Rich Lake Member is a medium gray (N5) to light gray (N7) calcareous bentonite clay (Reeves, 1970).

The lacustrine units of Tahoka age often contain 20 to 30 percent quartzose sand and 10 to 30 percent carbonate (both calcite and dolomite) although exact mineralogy depends on depositional location within the lake basin. Predominant clay minerals are illite and sepiolite with minor amouns of kaolinite, attapulgite and mixed layered clays. Other investigators

(McLean, 1968; McLean, et al., 1972; Bates, 1968; Leach, 1968) find similar kinds of minerals plus minor amounts of additional clay minerals. The clays of Tahoka age are predominantly whitish-blue (5BG) or greenish-gray (5G 5/1) in outcrop.

On the Southern High Plains, Recent time represents the interval since the climax of the Altithermal, 4000 to 5000 years B.P. (Frye and Leonard, 1965; Morrison and Frye, 1965). Reeves (1970) found no stratigraphic divisions of Recent age in the Southern High Plains playa basins, the Recent sediments in the larger lake basins such as Double Lakes being represented mainly by organic mucks and gypsum crystal mash.

The Quaternary stratigraphy of Double Lakes basin is similar to that of the other large lake basins on the Southern High Plains. Reeves (Leach, 1968) found three distinct time-stratigraphic units in the Lake Mound basin of Lynn and Terry Counties, Texas, only 13.3 km. west of Double Lakes. These units, of Recent, Tahokan, and pre-Tahokan age were distinguished by C^{14} dates from various lacustrine dolomites and stratigraphic relationships. The same three time-stratigraphic units are present in the Double Lakes basin.

Parry and Reeves (1968) and Reeves (1972) suggest that major lithologic differences between the early Pleistocene (Nebraskan and Kansan) lacustrine sediments and the late Pleistocene (Wisconsin) lacustrine sediments on the Southern High Plains are due to a change in source area caused by piracy of the ancient Portales River. However, major lithologic changes in the Wisconsin lacustrine sediments themselves in the West Texas area were due to regional climatic changes. Lacustrine units, therefore, have a marked resemblance from one large basin to another. For example, the abrupt change from lacustrine clays to thin carbonates in the upper part of the Tahoka Formation represents desiccation of the lakes during mid-Tahokan time. This period of desiccation, termed the Vigo Park interval (Reeves, 1970), correlates with a climatic change recognized from the Great Basin to Europe (Reeves, 1966a).

Late Pleistocene sands, clays, gypsiferious sands and dolomites outcrop sporadically around both playas in the Double Lakes basin. On the west side of the north playa and on the south end of the south playa the lacustrine section is up to 6 m. thick.

Two irregular lacustrine carbonates outcrop 4.5 to 6.0 m. above and 400 m. west of the present playa surface on the west side of the north playa. The upper carbonate (NTB-1) is dolomitic and was dated at 26,000 ± 1,250 years B.P. (Reeves, 1970). The dolomite is 0.6 and 0.85 m. thick, displays prominent "dishpan" (Bates, 1968) structure, numerous voids, and contains many dolomitic clasts in the matrix. The radiometric age shows that the carbonates and underlying clays are of pre-Tahokan (Rich Lake and possibly earlier) age.

The lower unit, about 1.2 to 1.8 m. thick, is calcium carbonate containing no dolomite. The unit is massive and structureless. Both the carbonate units dip less than 1 degree toward the present basin and are the only major occurrence of pre-Tahokan carbonate found in the lake basin. Pleistocene sediments of pre-Tahokan age stratigraphically underlying the Rich Lake carbonates consist mainly of clay and sandy clay, and contain no soft sediment dolomite which is found around stream entrants and springs in Mound Lake, 12.8 km. to the west.

The pre-Tahoka clays in the present basin are greenish gray (7.5GY) to black in color. Intermixed in the clays are both large (greater than 5 cm. across) and small gypsum crystals. Sand content is varied but usually ranges anywhere from 10 to 30 percent, with the higher percentages being in the upper part of the section. From core holes the small gypsum crystals appear to be growing within and parallel to the bedding planes of the clay layers; however, the larger crystals cut across the bedding at various angles. In hole 28 (Appendix c), the deepest drilled in the pre-Tahoka section, pyrite was found forming in the lower part of the section. At the contact between the pre-Tahoka and Recent sediments in the present playas there is a yellowish-red, gypsiferious, clayey sand. This layer is extremely porous and contains abundant water, which, after heavy rains, will rise in the hole to the present playa surface. There are similar zones throughout the lacustrine clays.

Sediments deposited during the Tahoka Pluvial are primarily calcareous clays, carbonates, and sands which outcrop around the present playas and underlie most of the present lacustrine plains. The Tahoka Formation reaches a maximum thickness of 6.0 m. in the subsurface and up to 10.5 m. in outcrops along the western edge of the south playa, reaching a maximum elevation of 945 m.

Along the western and southwestern edge of the south playa the Tahoka clays begin about 1.5 m. above the playa surface and extend to a height of 11.0 m. above the playa. Bluish clay is predominant, with thin intermixed units of carbonate and greenish clay. Where the escarpment is close to both playas the clay is a light pinkish-brown with a large percentage of gypsum (selenite) crystals intermixed randomly in the clay layer. At location L-6 and L-9 (Fig. 18) on the north playa, the clays are greenish-colored and the blue clay is absent. Both clay layers are overlain by lacustrine Tahoka sands. Fine- to medium-grained Tahoka sands intermixed with clay and streamers of organic debris outcrop along the eastern edge of both playas, the organic zones indicating periodic regressions of the lake during Tahoka time.

Tahoka carbonates are both calcite and dolomite, the majority being dolomite. The carbonate layers, seldom exceeding 0.6 m. in thickness, are the result of desiccation of near shore facies shortly after deposition. The dolomites are indurated on exposure, but are soft and crumbly when fresh. Calcite units are softer and thinner than the dolomite units, but the upper zone of calcite may become slightly indurated upon exposure. Bates (1968) states that the thin Tahoka dolomitic layers found in all the large lake basins were never subaerially exposed long enough to permit desiccation contortions. The indurated dolomites, which closely resemble Ogallala "caprock" caliche in hand specimens, often form benches in the Double Lakes basin, however, the caliche can be distinguished from the lacustrine carbonates mineralogically or with trace elements. Tahoka dolomites at the north end of the south playa (STB-1 and 2) yield C^{14} dates of 19,800 ± 500 and 20,300 ± 300 years B.P. (Reeves, 1970). Both units, which are overlain by Tahoka sands, fail to crop out on the south end of the north playa.

The dolomites indicate that at the beginning and at the end of the Tahoka pluvial, as well as during the mid-part of the pluvial, there were drier climatic conditions causing desiccation of the Tahokan lakes. The predominant sediment deposited during the rest of Tahokan time was clay and fine-grained sand.

Recent alluvial and lacustrine sediments in the Double Lakes basin, deposited in the last 4500 to 5000 years (the Medithermal interval of Antevs, 1955), consists of sand, clay, organic muck, and large amounts of salt. The centers of the playas contain sandy clays and organic debris, the sand percent increasing shoreward. Sands and clays are washed into the playas from the older fringing dunes and sandy lacustrine clays.

The salts present are gypsum, halite, and thenardite. Gypsum is the most abundant and is both detrital and primary in origin. Halite and thenardite are precipitated at surface when the water remains at at static level for long periods, thus the halite and thenardite are easily removed by deflation. The gypsum tends to concentrate in situ in the clays and organic mucks.

The average thickness of the Recent sediments in 0.67 m. to 0.85 m. The contact between the Recent and the pre-Tahoka clays is placed above a coarse, gypsiferious, sandy clay which is water saturated during and after periods of heavy rainfall. The gypsiferious clay, or gypsum mash, was probably formed by the severe desiccation during the Altithermal interval 7000 to 4500 years B.P. (Antevs, 1955).

3. Geologic History

Figures 20, 21, 22, 23, 24 and 25 illustrate the configuration and geologic history of the Double Lakes test site. At the south end of the basin the Cretaceous unconformity is flat (Fig. 19), the basin originally having bottomed on the Cretaceous Duck Creek and later having been incised into the Duck Creek Formation to the top of the Kiamichi Formation. To the northeast, the Cretaceous surface develops a noticeable sag beneath the present playas, probably reflective of the ancient drainage valley, and at the far northeast end the Cretaceous dips rapidly to the east (Fig. 24). However, at the far northeast end of the present playa complex the basin has again cut to about the Duck Creek-Kiamichi contact.

An understanding of the geologic history of the Double Lakes basin is complicated by depositional unconformities and lack of datable material. Reeves (1966a and 1966b) presents evidence that many of the

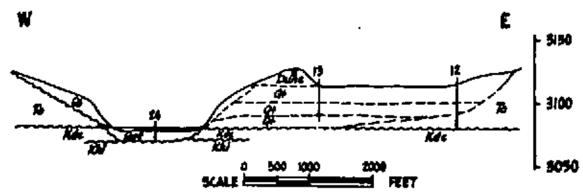


Figure 21 - Cross-section A, south playa of Double Lakes test site. Qt = Tahoka Formation, Qt_1, Qt_2, Qt_3, Qpt = pre-Tahoka Formation, Kdc = Duck Creek Formation, Kki = Kiamichi Formation

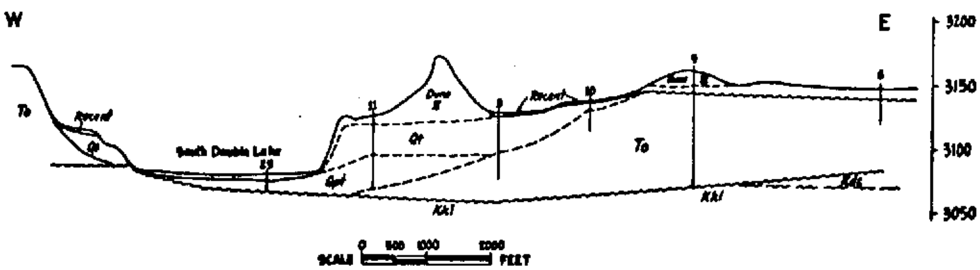


Figure 22 - Cross-section B, south playa of Double Lakes test site. Qt = Tahoka Formation, Qpt = pre-Tahoka, To = Tahoka Formation, Kdc = Duck Creek Formation, Kki = Kiamichi Formation.

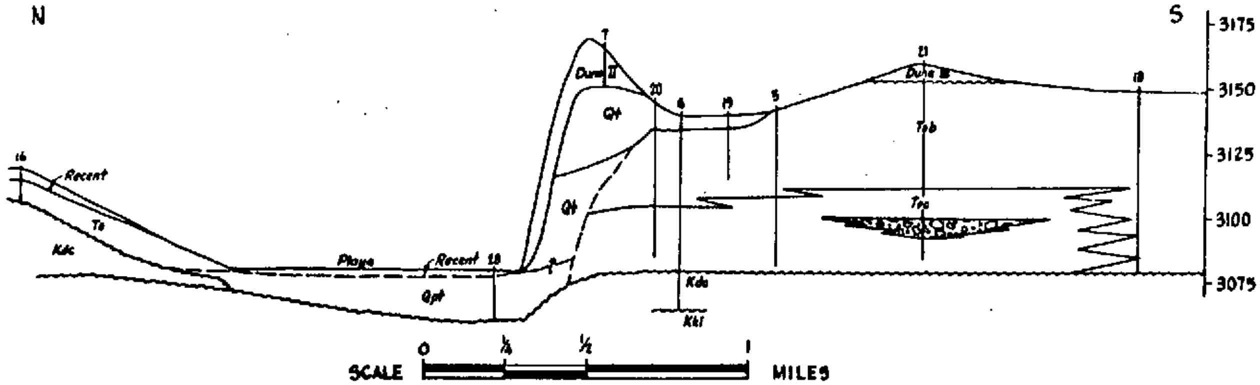


Figure 23 - Cross-section C, north playa of Double Lakes test site. Qt = Tahoka Formation, Qpt = pre-Tahoka, To = Tahoka Formation, Kdc = Duck Creek Formation, Kki = Kiamichi Formation.

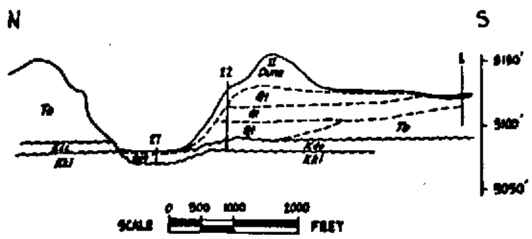


Figure 24 - Cross-section D, north playa of Double Lakes test site. Qt = Tahoka Formation, Qpt = pre-Tahoka Formation, Kdc = Duck Crook Formation, Kki = Kiamichi Formation.

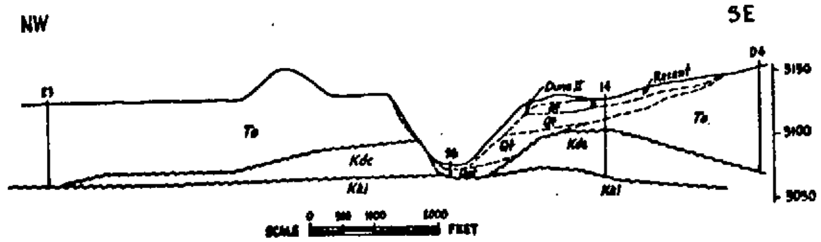


Figure 25 - Cross-section E, north playa of Double Lakes test site.

large pluvial lake basins on the Southern High Plains, such as Double Lakes, were once part of an open lake system interconnected by early Pleistocene drainage channels. The lake basins formed over Cretaceous topographic highs where the Ogallala Formation was unusually thin. Once the drainage channels eroded to the more competent Cretaceous limestone and shales, lateral erosion predominated.

The unconformity on the buried Cretaceous of the Southern High Plains exhibits over 60 m. of relief in some areas and incisement by stream valleys is common. Regional maps of the Cretaceous surface suggest a drainage channel trending toward the northeast and probably flowing into the old "Slaton" channel from the Double Lakes basin (Cronin, 1969; Goolsby, 1973), but the exact direction and placement of Ogallala drainage in the area is unknown. Ogallala gravels were dirlled in holes 21 and 23, but the Ogallala Formation in other areas surrounding the basin is comprised almost entirely of medium- to fine-grained sands and clays (Appendix C).

Presence of an Ogallala channel in the Double Lakes is suggested by: (1) the gradational dip of the caliche "caprock" toward the present playas (Fig. 26), (2) the basin in the Cretaceous around the south playa (Fig. 19, Section B, and Fig. 14), and (3) the browner-colored Ogallala sands on the east flank of the present playas which forms the oldest dune trend (Series III). However, if an Ogallala channel does exist in the Double Lakes area it can be expected to be narrow and deep, similar to the "Slaton" channel 8 miles to the north.

The absence of early Pleistocene-type lacustrine sediments in the Double Lake basin indicates that the drainage channel was not blocked until mid or late Pleistocene time. Reeves (1970: 1972) dates the capture (by the Pecos River) of the ancient Portales River and tributaries, the last major stream system to flow across the Southern High Plains from the Rocky Mountains piedmont plain, in post-Kansan but pre-Illinoian time. Thus, the Double Lake drainage probably became blocked and the Double Lake basin came into being during the Yarmouth interglacial period.

Cross-sections based on drill holes show that the pre-Tahoka lacustrine sediments failed to fill the basin, the upper level being 930 m. The pre-Tahokan

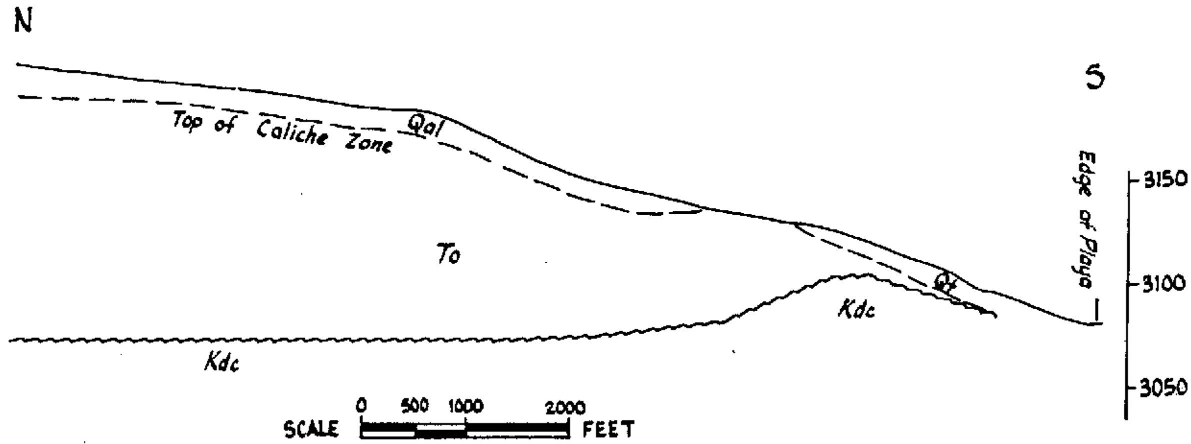


Figure 26 - Cross-section at north end of Double Lakes test site illustrating dip of Pliocene caliche into the lake basin.

lacustrine fill was then incised, probably by deflation, before Tahokan deposition began. This incisement then allowed deposition of Tahoka clays and carbonates at elevations below pre-Tahoka sediments. Near the end of Tahokan time the Double Lakes basin was filled to near maximum levels as indicated by shorelines on the west side of the south playa. The shorelines are at elevations of 932, 939, and 945 m.: these are 6.0, 13.5, and 20 m. respectively above the present playa.

Deflation of Tahoka and pre-Tahoka sediments and formation of the present playas occurred after late Tahokan time, probably becoming most severe during the Altithermal interval. During the Altithermal interval, dunes were again built by deflated lacustrine sediment. The areas between the two playas remained a ridge which was later covered by eolian sands.

One to 1.2 m of Recent sediments have accumulated in both playas. This material, originating from the flanking dunes and older lacustrine sands and clays surrounding the playas, as well as the precipitated salts, is periodically deflated to the northeast, accumulating as the youngest (Series I0 dunes when the playas are dry.

The three distinct dune ridges along the eastern flank of the Double Lakes basin (Fig. 27) have been correlated with Melton's (1940) Series I, II, and III dunes by Reeves (1965). Series I dunes formed in the past 5000 years, the prevailing wind direction being N 25° E. Series II dunes formed between 5000 and 15,000 years ago due to a prevailing wind of N 50° E, and Series III dunes formed over 15,000 years B.P., the prevailing wind direction being S 60° to 70° E (Melton, 1940). Melton (1940) found that Series II dunes suggested a paleo-wind direction of N 40° to 70° E from studies north of the Double Lakes area, but Reeves (1965), working at and around Double Lakes, found Series II dunes formed mainly from a paleo-wind direction of S 50° to 90° E.

The Series I dunes at Double Lakes trend N 50° W along the north edge of the southern playa, at the north end of the north playa and sporadically along the western edge of the north playa. Southwest of the playas occur the "Tivoli" sands of the Recent age, (Mowery and McKee, 1958), but these are not considered part of the Series I dunes. The prevailing wind

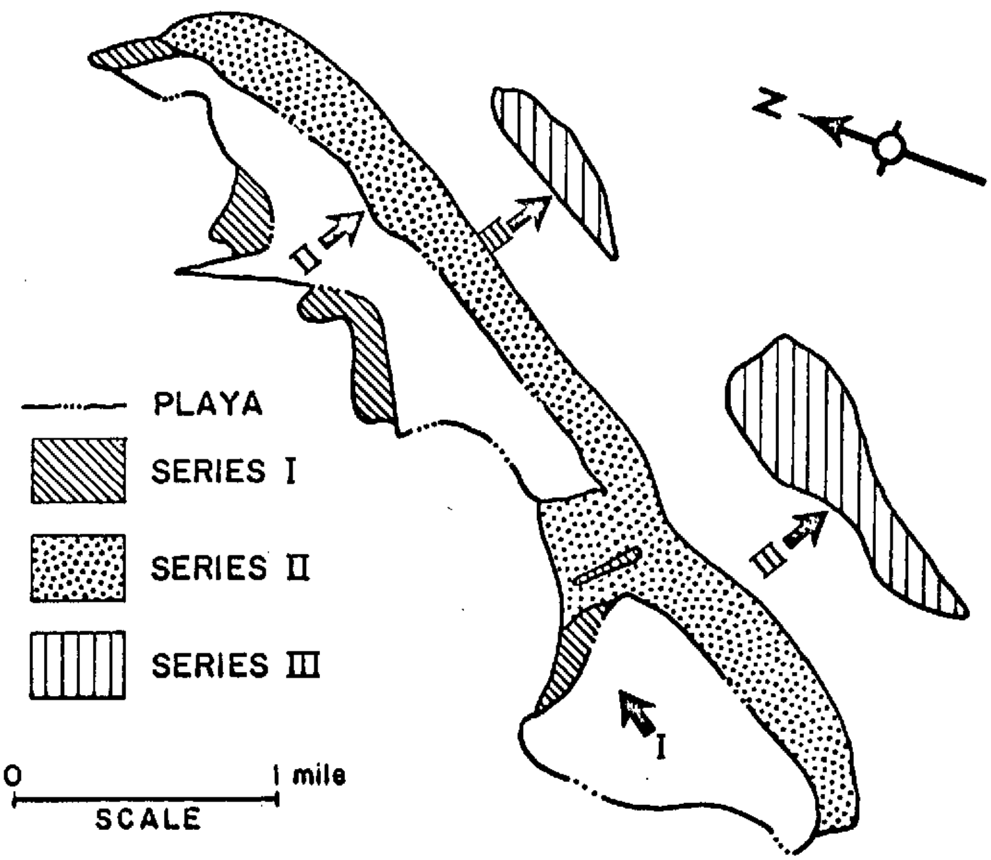


Figure 27 - Dune series in the Double Lakes test site area. Arrows refer to respective dune-forming wind direction.

of N 25° E is best indicated by the linear dune at the north end of the south playa. Mineralogically, the Series I dunes consits of fine- to medium-grained quartzose sand and clay with intermixed gypsum crystals. The predominant color is a light brown (2.5Y 7/2).

Series II dunes trend N 60° E with a prevailing wind direction that agrees closely with that suggested by Reeves (1965). Series II dunes are the largest of the dune series and border the eastern edges of both playas. Extensive erosion has produced deep gullies normal to the dune trend; outcrops and drill holes show that much of the dune relief is caused by buried lacustrine sediments. Drill holes 11, 22, and D-5 (Appendix C) show that the dune sands themselves are probably no thicker than 20 feet.

The Series II dunes, which rise 12.0 to 15 m. above the lacustrine flat to the east and 27.0 to 30.0 m. above the present playa surfaces, rest on lacustrine sand and clay, which is underlain by a friable quartzose sand. The lacustrine sediments beneath the Series II dunes have been dated at 20,850 years B.P. (Reeves, 1965), thus the dune encroachment correlates closely with Melton's date of 5000 to 15,000 years B.P. Series II dunes are now stabilized by vegetation and are undergoing pedogenic processes illustrated by the illuvation of clay 0.3 to 0.9 m. below the surface. There is also a gradual buildup of calcium carbonate at or below 0.9 m. To the east and behind the Series II dunes occur lacustrine sediments immediately below surface.

Mineralogically, the Series II dunes are well- to sub-rounded, fine- to medium-grained quartzose sand with intermixed clay particles and gypsum crystals. The color is between grayish-yellow brown (10YR 4/2 to 6/2) and grayish-yellow (2.5Y 5/2 to 6/2).

Series III dunes, rising 9.0 to 12.0 m. above the Tahoka surface, have a well-developed soil profile with a pronounced carbonate buildup at about 0.9 m. These dunes overlie an old soil profile at a depth of approximately 4 feet, with Ogallala sands and clays occurring beneath the soil. The mineralogy of Series III dunes closely resembles that of the underlying Ogallala sediments, thus the dunes were probably created by deflation of Ogallala sediments to the west.

C. METEOROLOGY

1. Climatic Summary

The climate of the test-site area is semi-arid, transitional between desert conditions on the west and humid climate to the east and south-east. The mean annual precipitation is slightly greater than 46 cm., varying from a record maximum of 105 cm. (in 1941) to a record minimum of 22 cm. (in 1917). Maximum precipitation usually occurs during May (May, 1941 - 32 cm.), June and July when warm, moist tropical air is carried inland from the Gulf of Mexico. The airmass produces moderate to heavy afternoon and evening convective thunderstorms, sometimes with hail. These showers or squalls are generally of short duration and may be scattered over a wide area or organized in narrow lines along or ahead of a frontal discontinuity.

It is important to recognize that the sequence of events leading to precipitation in one season of the year may not be the same as that producing precipitation in another season of the same year. Over most of Texas the heaviest rainfall occurs in the spring and fall where a dominant portion of the annual precipitation falls in the six month period from May through October. The heavy rainfall in late spring and early summer is usually the result of convection set off by frontal activity. The highly localized nature of the precipitation is associated with the equally localized field of vertical motion. Summer rainfall is made up of scattered showery developments which depend mainly upon daytime heating, low-level moisture, and the absence of subsidence aloft. During much of the summer, the extension of the Atlantic anticyclonic westwind brings upper-level stability and inhibits vertical development in any but isolated cases. General rainfall covering large areas with a duration greater than a few hours is associated, even during the summer season, with frontal activity.

During late summer and early autumn rainfalls over most of Texas is mainly the result of tropical disturbances moving northward and westward from the Gulf of Mexico. In the plains area, frontal passages are becoming more frequent, and this, coupled with the Gulf moisture, leads to an extension of the summer raining season into the early fall. Late autumn and winter rains are usually the result of warm moist Gulf air overrunning continental polar air associated with a strong winter anticyclone. The period from early winter until mid-spring is characteristically dry. Precipitation averages over a 50-year period indicate that 80% of the annual rainfall occurs during the seven month period, April through October.

Rainfall records at Lubbock are nearly complete since 1911. Frequency distributions of rainy-season precipitation based on this period of record are shown in Fig. 28. The ordinate on this diagram is percentage cumulative frequency of occurrence while the abcissa is precipitation in inches. As one example of interpreting the curves, note that in May, precipitation amounts greater than 5 cm. were reported about 55% of the time. Thus, based on these data sample, there is a 55% chance that precipitation during May will be greater than 5 cm.

The normal annual temperature for the area is 59.7°F. The warmest months are June, July and August with a normal daily maximum in July of 92°F. The record maximum temperature of 107°F occurred in June, 1957 and July, 1958. The coldest months are December and January with a normal daily minimum temperature in January of 25.4°F and monthly mean of 39.2°F. The minimum temperature of -16°F occurred in January, 1963. Essentially the Lubbock area is sunny, having about 3200 mean annual total hours of sunshine.

Winds are strongest during intense thunderstorms but are of short duration. Mean wind speeds are rather high, (26.6 km./hr.) with the surface not offering as much resistance to wind movement as in locations with taller plant cover or more uneven topography. The strongest winds occur during February, March and April, when low pressure builds in front of advancing cold fronts sweeping out of the Rocky Mountains. The prevailing wind direction is from the southwest.

2. Test Period Data

The locations of the weather monitoring instruments at the test sites is shown on Figure 29. At the test site, temperature, relative humidity, wind speed and precipitation were measured on a continuous basis and recorded on strip charts. Precipitation is itemized in Appendix E and Appendix F illustrates daily maximum and

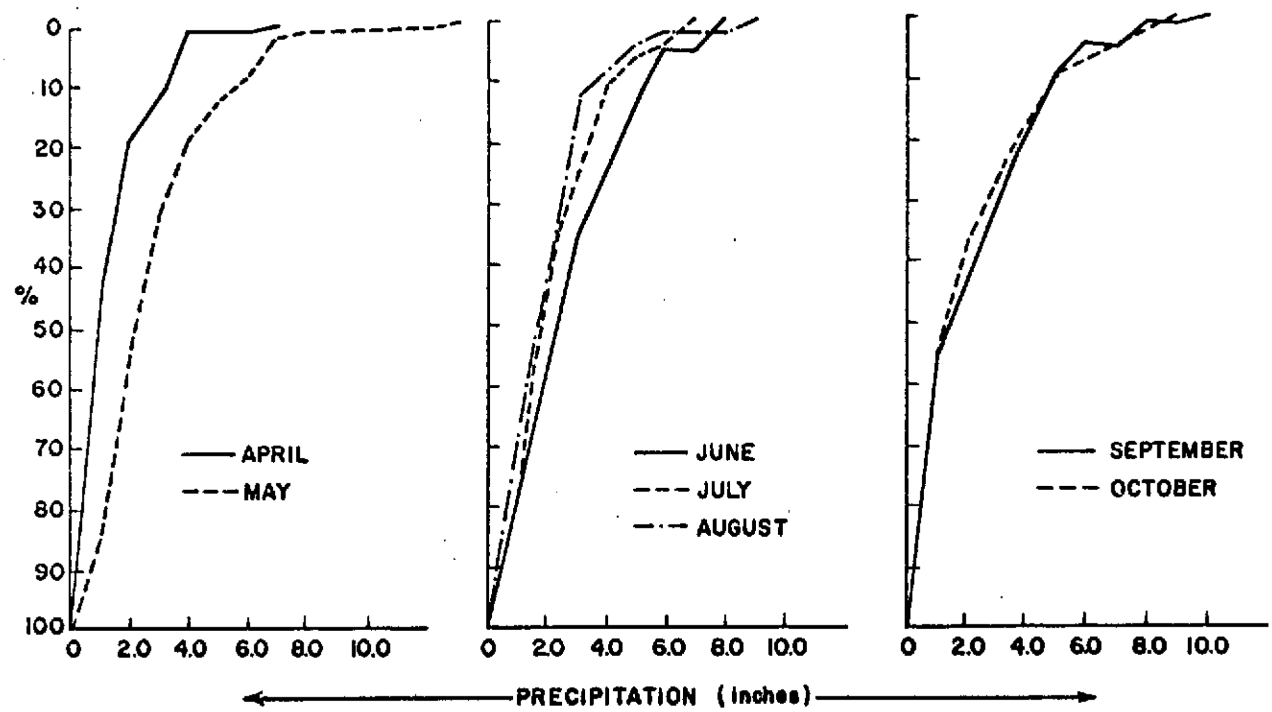


Figure 28 - Precipitation frequency Ogives, Lubbock, Texas 1911-1968.

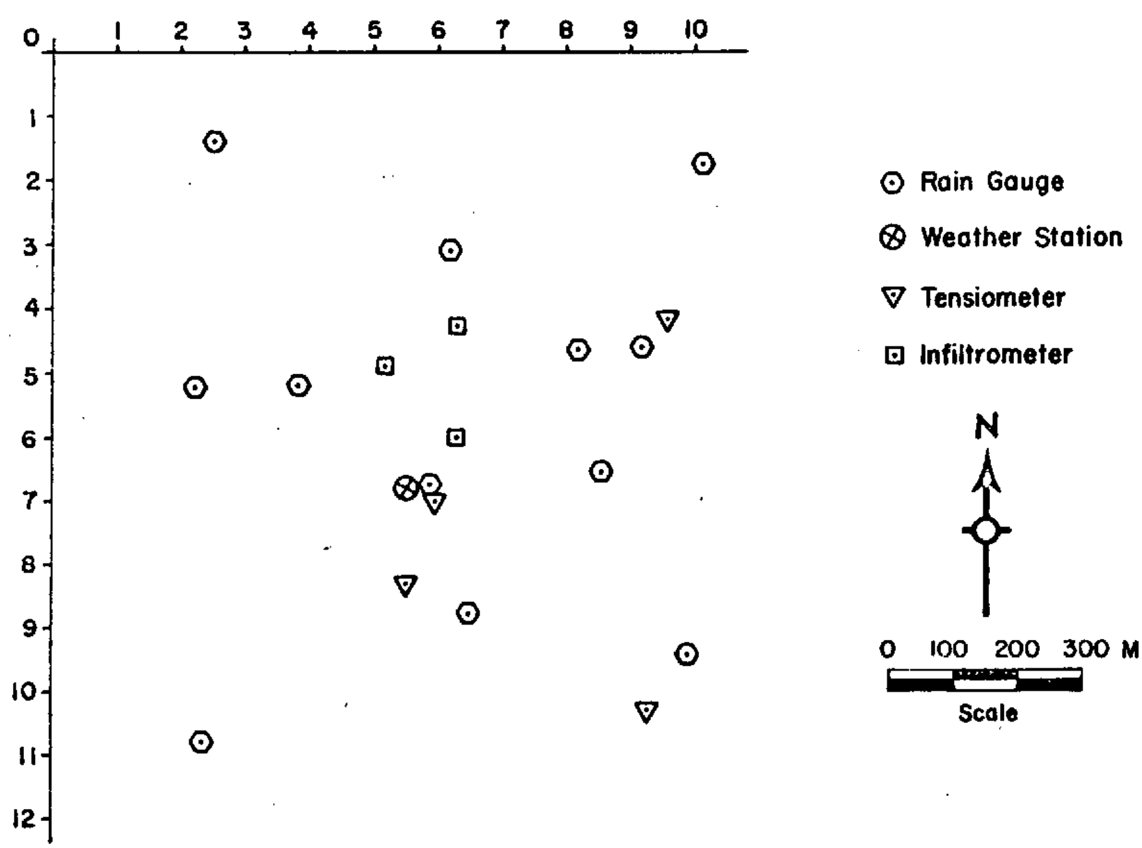


Figure 29 - Locations of weather monitoring instruments at the test sites: a) Double Lakes, b) T-Bar Lake.

minimum temperatures for each test site. Note by examining both sets of data that precipitation during the warm season usually occurred as short-lived, occasionally intense showers or thunderstorms which may have been related to frontal activity or to intense convection set up by surface heating in a moist air mass.

Appendix G contains soil moisture data secured by the neutron probes (Fig. 28). Figure 30 illustrates the soil moisture profile at Double Lakes from probes #1 and #2 and Figure 31 illustrates the soil moisture profile at the T-Bar site using all four probe stations. The gaps in the profiles are periods when data was either not secured or was obviously faulty. In order to allow direct comparisons, precipitation is also shown by the bar graph at the bottom of both figures. However, because sampling of soil moisture was not continuous, but at finite intervals, it is not possible to compute lag correlations in order to relate soil moisture response to different precipitation rates and amounts. Nevertheless, several qualitative comparisons can be made. For example, the 5.4 cm. of rain which fell in 1 1/2 hours on September 5, 1972, at T-Bar did not influence soil moisture, apparently due to the high runoffs created, whereas the 6.0 cm. of rain, which fell during a 20-hour period on October 19-21 at T-Bar, was accompanied by minimal runoff and maximum infiltration. In case of snow, soil moisture response was significant (see February 8-9, 1973, event) due to the low precipitation intensity and high albedo.

The total soil moisture and soil moisture response to a precipitation event at both sites was greatly influenced by the soils themselves - in other words, the geographic location of the probes. At the Double Lakes site one probe (#4) was installed on the north lake playa, one on Drake soil between the playas (#3), one on the massive dune (Drake soil) along the east side of the playa (#2), and one on Wisconsin (Portales soil) of the basin (Fig. 29). However, reliable, consistent data was only derived from probes #1 and #2 (Fig. 30). Figure 30 shows that soil moisture was consistently higher and that the response to precipitation events was consistently greater at probe location #1 (Portales soil-clay) than at location #2 (Drake soil-silty sand). This apparently reflects the greater permeability of the Drake soil, the water-holding capacity of the Portales soil, and the lag time between

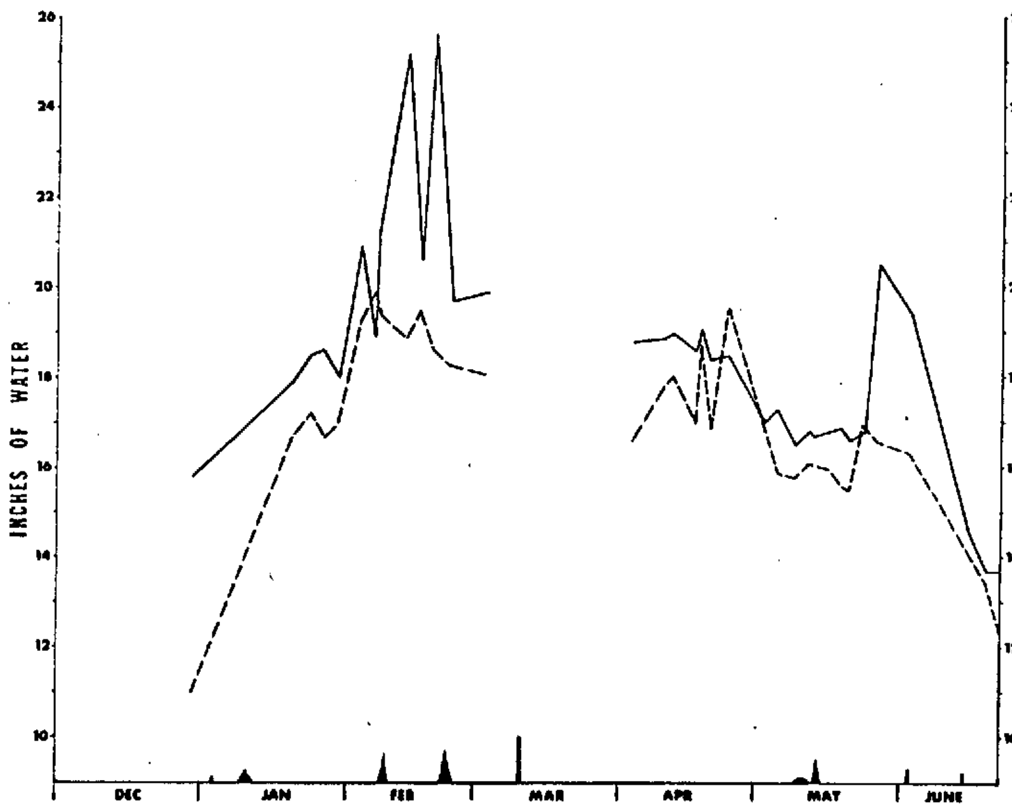


Figure 30 - Soil moisture profile recorded by neutron probes at the Double Lakes test site. Probe #1 is the solid line, #2 the dashed line.

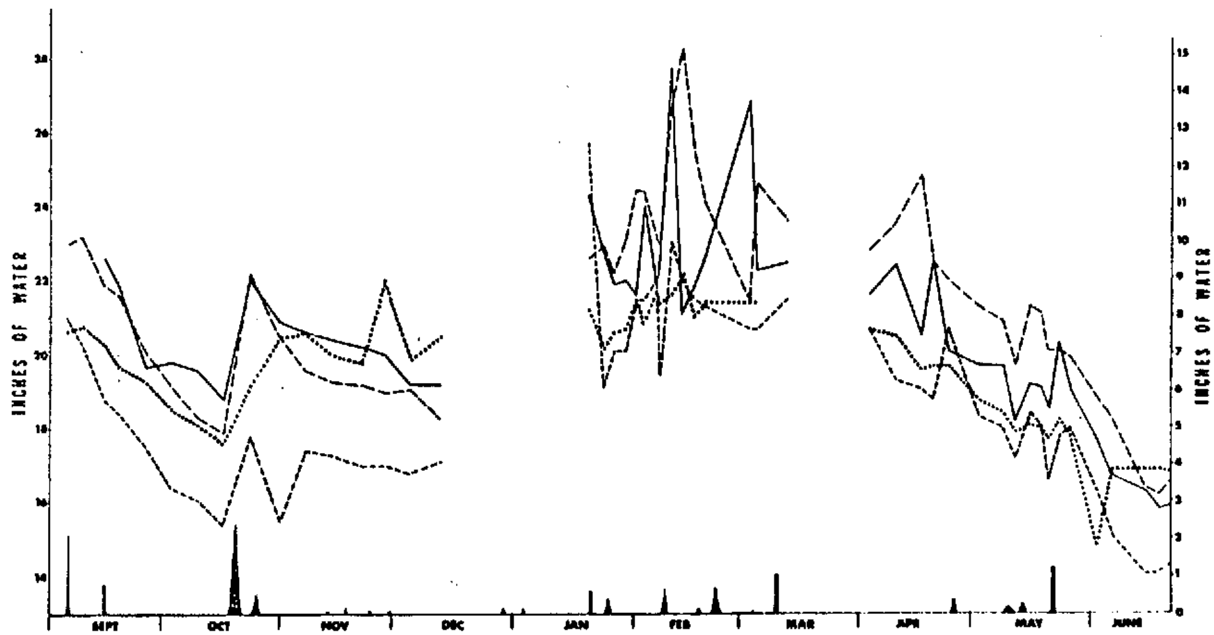


Figure 31 - Soil moisture profile recorded by neutron probes at the T-Bar playa test site. Probe #1 is the solid line, #2 the dotted line, #3 the dashed line and #4 the large dashed line. The curve for probe #4 must be read to the right hand vertical scale.

the precipitation events and the probe readings. Readings taken shortly after a precipitation event would expectantly show more moisture and a greater response at probe #2 than at probe #1; however, a few days lag between the event and the reading allows the moisture front, taking advantage of the permeability in the sandy soil, to move beyond the range of the probe.

At the nearby T-Bar site four neutron probes were installed and except for two gaps, gave consistently reliable readings over a 10-month period. Probe #1 was located on the edge of the playa on Randall clay, probe #2 low in the basin on the Acuff soil, probe #3 high on the basin on Acuff soil, and probe #4 high on the basin on Friona soil. As Figure 31 shows, there was reasonable correlation between probes #1, #2 and #3, but probe #4, on the Friona soil, which is underlain by hard indurated caliche, was consistently dryer. Probe #1 would be expected to show the greatest soil moisture because of its playa location, however, probe #2 shows more moisture, perhaps because of the increased permeability of the Acuff soil. That the differences in moisture content between probes #1 and #2 is mainly a function of permeability is also suggested by their relative responses to certain precipitation events. For example, the light snows in November, 1972, cause an increase in moisture at probe #2 location, but the runoff was apparently not great enough to reach the playa (Fig. 31). However, the heavier snow of February 9 was immediately reflected at all four probe locations, probes #1 and #2 (low in the basin) showing the greatest increase (Fig. 31). By February 10 the moisture content was falling at probe #1 and continued to do so until February 13th when the infiltrating melt water from the snow started to reach the basin: at about the same time the moisture peaked at probe #2. Thus, during the period February 13- March 2, probes #1 and #2 illustrate a mass transfer of soil moisture into the basin proper. The contributing effect of the 5-hour rain which fell on February 22 cannot be determined for probe #1 but may be reflected at probe #2 on March 2. On May 22 a 3.0 cm. rain is reflected by increases in soil moisture at probe locations #1, #3 and #4, but soil moisture at probe #2 fails to exhibit any influence on the precipitation.

Correlation coefficients between the probe locations are illustrated in Table 5.

TABLE 5 - CORRELATION COEFFICIENTS BETWEEN NEUTRON PROBES AT THE T-BAR PLAYA SITE

PROBE NUMBERS	CORRELATION COEFFICIENT
1-2	0.78
1-3	0.73
2-3	0.71
1-4	0.81
2-4	0.83
3-4	0.71

D. HYDROLOGY

Appendix G summarizes the climatological data recorded at the T-Bar playa site and at the Double Lakes test site. Precipitation data at Double Lakes shows only three events of 2.54 cm. or more (February 26, May 9, July 20, 1973) and a total recorded precipitation of about 22.0 dm. between Debember 30, 1972 and August 27, 1973. At the T-Bar playa site only four precipitation events greater than 2.54 cm. occurred during the period September 2, 1972 to June 29, 1973 (September 2 and October 17, 1972 and March 3 and May 16, 1973), the total precipitation for the period being about 34.0 cm.

As Table 6 illustrates, the water area of the Double Lakes playas varied considerably during the monitoring period whereas the T-Bar (playa) site was wet for only two satellite passes (August 16 and October 9, 1972). The "counts" describing the length and area of the flooded playas and the area of the surrounding mud flats were produced on the SRI-ESIAC. These counts have then been translated into sq. km. of water and mud area for ecah good pass date for both the north and south playas of the Double Lakes test site. Table 6 also illustrates the recorded depth of water measured by a field observer (North playa only).

Measurement of the film density of the water in the Double Lakes test site was conducted with an electronic Density Control Unit built into the I^2S Density Slicer. The DCU is adjustable over the density range from 0.0 to 3.45 in steps of 0.15; calibration was to the step wedge on the MSS films. Readout was from a digital panel on the Density Slicer. Table 7 illustrates the variation of density readings with changes in water depth and season. Naturally variations in water turbidity and productivity could have also induced variations in the density readings.

Density differences were also displayed along a movable vertical axis on the console monitor. The density curve is smooth for deeper water and becomes jagged and reatreats to the base line as the water becomes shallower. Figure 32 illustrates the density profile for the partially flooded north playa of the Double Lakes test site on 16 August, 1972 (A) as opposed to the density along the dry and muddy playa on 11

Table 6 - Summary of water and mud extent in the Double Lakes playas correlated with water depth.

DATE	WATER COUNT N	WATER COUNT S	MUD COUNT N	MUD COUNT S	LENGTH WATER IN MM. N	LENGTH WATER IN MM. S	WATER AREA IN SQ. KM. N	WATER AREA IN SQ. KM. S	MUD AREA IN SQ. KM. N	MUD AREA IN SQ. KM. S	N. PLAYA WATER DEPTH IN CM.	T-BAR WET OR DRY
7-29-72	900	1180	1240	1680	1.5	1.4	0.64	0.83	0.24	0.35	± 5.00	DRY
8-16	1990	1640	3400	1730	2.2	1.0	1.13	0.93	1.93	0.98	23.00	WET
10-09	2196	2335	2396	2932	3.3	1.9	1.25	1.32	1.13	1.66	30.00	WET
11-14	2360	2300	ND	ND	3.0	1.9	1.34	1.30	----	----	36.00	WET
12-02	2575	2140	ND	ND	3.0	1.8	1.46	1.21	----	----	40.00	DRY
*2-12-73	2781	3111	ND	ND	3.2	1.7	1.40	1.61	----	----	41.00	DRY
3-20	2600	2330	ND	2670	3.1	1.7	1.48	1.32	----	1.52	40.50	DRY
4-07	2680	2015	ND	2060	3.0	1.6	1.52	1.15	----	1.17	41.00	DRY
6-18	940	0	1125	850SA	1.5	0.0	0.53	----	0.64	----	2.54	DRY
7-06	0	0	0	800SA	0.0	0.0	----	----	----	----	0.00	DRY
7-24	900	860	1000	920	1.5	1.1	0.51	0.48	0.56	0.51	2.54	DRY
*8-11	0	1059	752	1733	0.0	1.0	----	0.55	0.39	0.35	0.00	DRY

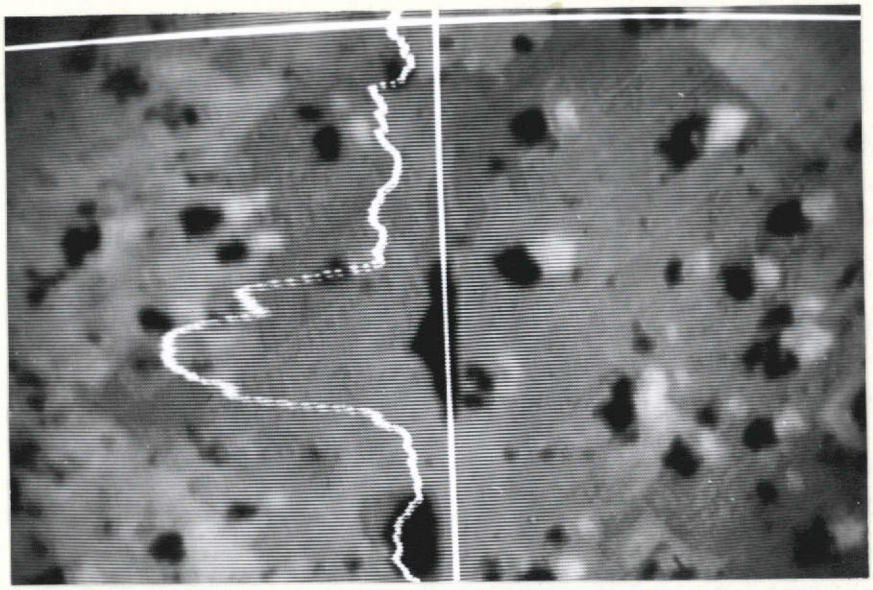
$\text{Area} = \frac{\text{(count)}}{1756.25}$ SA = salt crust ND = not determinable

$^{*}\text{Area} = \frac{2\text{(count)}}{3869}$

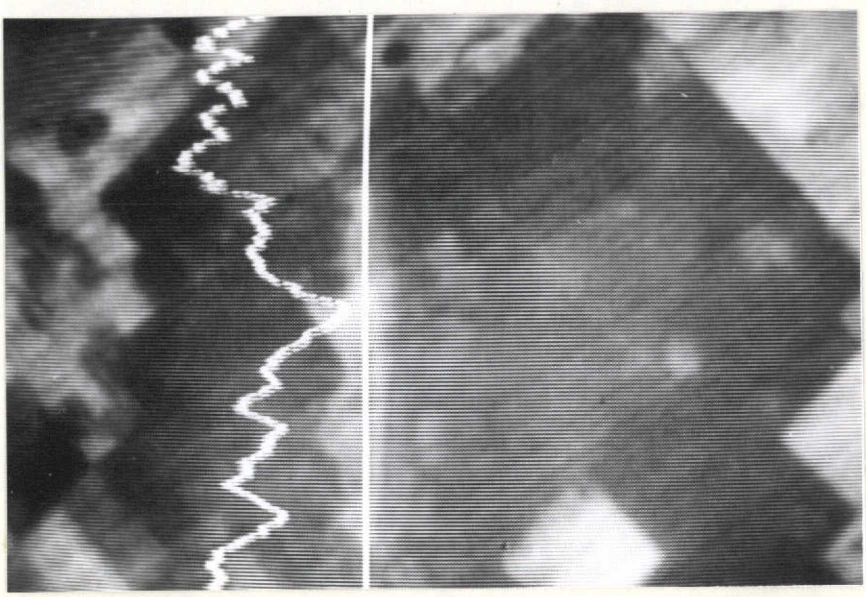
TABLE 7 - DENSITY VARIATIONS WITH CHANGES IN WATER DEPTH AND SEASON AT DOUBLE LAKES TEST SITE

MEASUREMENTS MADE ON MSS BAND 7.

DATE	WATER DEPTH IN CM	DENSITY READINGS, NORTH PLAYA DEEPEST WATER	MUD AREA	SALT CRUST	PICTURE
July 29	5.08				
Aug 16	22.86	+1.68	+1.43	0.93	1 and 2
Oct 9	30.48	2.15	+1.80	+1.73	
Nov 14	35.56	NM	NM	NM	These pictures too dark at density setting for measurement
Dec 2	40.00	NM	NM	NM	
Feb 12	40.64	NM	NM	NM	
Mar 20	40.38	+2.25	-----	-----	3
Apr 7	40.64	+2.23	+1.89	-----	4
June 18	2.54	+1.98	+1.66	1.39	5
July 6	0.00	-----	-----	1.19	6
24	2.54	+1.84	+1.64	1.39	7
Aug 11	0.00	-----	+1.56	1.17	



(A)



(B)

Figure 32 - Density profiles across the north playa of the Double Lakes Test Site. (A) from 16 August, 1972 and (B) from 11 August, 1973.

August, 1973 (B). Notice how the density profile falls on crossing the slightly raised part of the playa at the north end where the playa constricts (Fig. 32a). The slight "bump" on the profile at the north end of the playa in Fugyre 32a is caused by a muddy area due to subterranean spring flow. On Figure 32b the density profile is jagged, reading a low point where the playa constricts at the north end. The southern half of the playa was muddy at the time of this pass as indicated by the jagged profile and substantiated by field evidence.

SECTION IV

COST/BENEFIT ANALYSIS

Receipt of the first ERTS-1 imagery of the Southern High Plains of West Texas and eastern New Mexico revealed that a regional census of the tens of thousands of ephemeral lake basins could be quickly made.

The arid and semi-arid lands, comprising at least 30 percent of earth's dry land surface, are climatically characterized by wide temperature extremes, intermittent torrential precipitation, and natural depressions known as pans (South Aftica), chotts (Tunisia), sabkhas (Sahara Desert), or playa lake basins (United States). During certain times of the year, and during west years, these natural basins fill with fresh water which is, for all practical purposes, lost by evaporation before it can be utilized for livestock, agriculture, or aquifer recharging.

In most arid areas, ephemeral playa lake water is the only surficial fresh water supply, thus the lake water can be utilized for crop irrigation or stock, if available at the right time. Unfortunately, most crops are fully "irrigated" by the storms which fill the lake basins, and by the time surrounding crops again need water, most of the water in the lake basins will have evaporated. Thus, the best economic use for such water is to recharge the local aquifer.

Artificial recharge procedures are admittedly expensive, but have been surprisingly successful in many areas of the world (Tison, 1970). However, a reliable estimate of the amount of surface water available at any time and throughout the year in an arid area is needed before a decision can be made as to whether local aquifer recharge would be econimically feasible. To date, such figures have been impossible to obtain on a regional basis, even in areas of excellent access such as the Southern High Plains of West Texas, let alone in areas such as the Sahara or parts of Australia. For example, on the Southern High Plains of Texas it was originally thought that 37,000 playa lake basins stored 1 to 1.5 million acre-feet of runoff anually, but subsequent surveys (Schwiesow, 1965; Grubb and Parks, 1968) indicate 19,241 to 16,734 lakes with an available runoff storage of only 365,122 acre-feet.

However, the total amount of water caught by the lake basins is a function not only of number, but of filling frequency and volumetric parameters, neither aspect of which has been thoroughly studied. Such studies are presently underway by several agencies.

An initial count of the number of water-filled playa lake basins on the Southern High Plains was made by SRI. SRI personnel counted 6631 water-filled playa lakes from scene 1078-16524-7 (9 October, 1972), 353 to 447 being within the recent storm path imaged on the scene. A wet lake census of the entire Southern High Plains using a mosaic of ERTS-1 transparencies was then conducted by SRI. Approximately 10,036 wet lakes were counted which contained from 182,561 to as much as 580,098 acre/feet of fresh water.

As shown by Table 8, the three conventional methods considered for taking a lake survey utilize ground transportation, a light airplane, and black and white aerial photographs. The cost of making the survey using multispectral (MSS) and computer compatible tape (CCT) data from the ERTS-1 satellite. The area considered consisted of approximately 30,000 square miles, and non-technical labor was figured on the basis of \$50/day or \$1000/month. Survey frequencies are stated as a maximum possible in a year's time and do not include "rebated" due to inclement weather. Naturally, no costs for the satellite system hardware, operation, or maintenance are used.

Seemingly, the simplest method of conducting the survey would be by automobile or light truck, but the time necessary to thoroughly inventory an area of 30,000 square miles reduces available coverage to 4 surveys/year (Table 8). Costs, concentrated in labor, transportation and subsistence, would average about \$0.27/square mile. However, it should be advised that these figures are based on a well-developed transportation network. In other areas where road networks are poorly developed, the cost would rise accordingly. For example, it took two men seven days to locate only 26 small farm ponds in Arizona.

Use of a light airplane for the survey would cut costs substantially and increase available survey frequency to 30/year, although frequency could be further increased by using additional planes and personnel. With an in-house pilot, cost is reduced to about \$0.07/square mile, yet cost is naturally a func-

Table 8 - Cost/benefit analysis of lake census of Southern High Plains, Texas.

	GROUND SURVEY	AERIAL PHOTOGRAPHS	AIRPLANE SURVEY	SATELLITE SYSTEM MSS	CCT
Photo Repro/ Print charges	---	Contract	---	$45	$200 CPU 600 print chg.
Miles traveled	14,000	---	5,000	---	---
Method of travel	automobile	airplane	airplane	satellite	satellite
Maximum[3] Available frequency	4/year	on call	30/year[4]	36/year	36/year
Accuracy	Excellent	Excellent	Poor	Excellent	Excellent
Time-man hrs.	1064/survey	---	60/survey	---	---
Labor cost[2]	$4000	Contract	$1000	$250	$216 CPU time
Transportation/ Field Expense cost	$2100	Contract	$600	---	---
Photo or map cost	$300	Contract	$300	$5.00	no charge
Scale[1]	1:24,000	1:20,000	1:24,000	1:300,000	1:24,000
Size of area	30,000 sq mi	30,000 sq mi	30,000 sq mi	30,000 sq mi	30,000 sq mi
Average cost/ square mile	$0.7/ sq mi	$2.00/sq mi	$0.07/sq mi	$0.01/sq mi	$0.03/sq mi
Total cost	$8000	$60,000	$2000	$300	$1000

[1]scale used for mapping or scale of images or CCT data most workable

[2]labor based on man @$1000/mth or $50/day CPM cost about $54/scene
Printer charge 20¢/page of 66 lines

[3]frequency does not allow for inclement weather

[4]use of one plane only

tion of type of airplane used. One difficulty in the system is that navigation becomes a problem, particularly in the strong crosswinds and flat terrain which characterize many semi-arid areas. Thus, accuracy would be probably somewhat less than that of a ground survey.

The problem of unacceptable accuracy from a light plane census can be reduced by using aerial photographs, however, the cost per square mile skyrockets by a factor of 29 to approximately $2.00/square mile, totaling about $60,000/survey. The use of aerial photographs for a wet lake survey is, therefore, not feasible, particularly with the high frequencies required.

Use of ERTS satellite data (Table 8) reduces costs to the range of $0.01 to $0.03/square mile. Labor costs are difficult to compute as the time necessary for the counting, using photographic enlargements of the MSS imagery, depends on quality of the MSS data, photographic reproduction quality, and experience of the counter. Likewise, costs using CCT data depend on whether the use agency has an in-house computer facility, on respective prorata of depreciation charges, and whether contract computer facilities must be used. Other variables are, of course, individual CPM and print charge rates. Figures used in this study were based on out in-house rates (IBM 370) which, admittedly, may be minimal when compared to industry.

Thus, the use of ERTS-1 MSS and CCT imagery for conducting a census of water-filled lake basins in semi-arid and arid areas results in a 200 to 66-fold reduction cost, respectively, when compared to taking the census using conventional aerial photographs. The satellite imagery also has the advantage of an 18-day period. If, however, a more frequent period is required, the cheapest method is by light airplane, the cost being double that of a CCT survey. As shown by Table 8 even the poorest of the semi-arid to arid countries of the world can afford to monitor their ephemeral lakes by use of satellite imagery if provided by a governmental agency, thus enhancing the predictability of extended drought conditions.

SECTION V

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are the result of this investigation:

1) ERTS-1 imagery can be used to trace surface moisture paths of isolated storm cells providing precipitation falls on a dry surface within a reasonable period preceeding the satellite pass.

2) ERTS-1 MSS imagery pinpoints water-filled lake basins as small as 10 acres. Therefore, such imagery can be used for a visual census of such small water-filled lake basins.

3) ERTS-1 MSS imagery, from digital printouts of CCT, also can be used for a census of water-filled lake basins as small as 2 acres.

4) Use of ERTS MSS imagery reduces the cost of such a lake census to about $0.01 per 1.61 sq. km. from the $2.00 per 1.61 sq. km. when using conventional aerial photography. Cost of using CCT data for such a survey is in the neighborhood of $0.03 per 1.61 sq. km.

5) ERTS MSS color composites are useful for distinguishing the muddy areas of playas from the water-covered areas.

6) ERTS MSS color composites are particularly useful for determining extent of water in large playas.

7) ERTS imagery is useful for general soils mapping.

8) ERTS imagery, when displayed in time-lapse sequence on film loops, illustrates:

A) Changes in water level in large lakes,
B) Changes in water depth in large lakes,
C) The annual flooding cycle of the semi-arid lake basins, and
D) The vernal advancement and retrogradation of both natural vegetation and planted crops.

9) The period of satellite passes needs to be reduced from the ERTS-1 18-day cycle, particularly for

use with large shallow lakes typical of semi-arid to arid areas. This is because such lakes may completely evaporate between passes of an 18-day period.

10) Changes in soil moisture could not be determined from the satellite imagery.

Essentially it was difficult, if not mostly impossible, to correlate the observed water balance ecosystem and geology/morphology of the test site with the satellite data mainly due to the long satellite period, resolution of the system, and surficial character of the sensors.

SECTION VI

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APPENDIX A

SOIL MORPHOLOGY

TEST SITE: Double Lakes

SOIL: Amarillo

Horizon	Depth (cm)	Morphology
A1	0-23	Brown (7.5YR 4/2) loam; weak medium granular structure; hard, very friable; common fine roots; noncalcareous; clear smooth boundary.
B22t	23-48	Brown (7.5YR 4/2) sandy clay loam; weak, coarse, prismatic breaking to moderate, medium, subangular structure; very hard, friable; common fine roots; common, thin, continuous clay films on ped faces; noncalcareous; clear wavy boundary.
B23t	48-84	Brown (7.5YR 4/4) sandy clay loam; moderate, medium, subangular blocky structure, very hard, friable; few fine roots; few patchy clay films, noncalcareous; gradual wavy boundary.
B24t	84-114	Reddish brown (5YR 5/4) sandy clay loam; moderate, medium, subangular blocky structure; very hard, friable; few patchy clay films; calcareous; gradual wavy boundary.
B25tca	114-	Reddish yellow (5YR 7/6) sandy clay loam; moderate and weak, medium, subangular blocky structure; common fine clay masses; 2- percent indurated calcium carbonate nodules; extremely calcareous.

TEST SITE: Double Lakes

SOIL: Arvana

Horizon	Depth (cm)	Morphology
A1	0-13	Reddish brown (5YR 5/4) loam; moderate, medium, granular structure; slightly hard, friable; common firm roots; noncalcareous; clear smooth boundary.
B21t	13-38	Dark reddish brown (5YR 3/4) sandy clay loam; moderate, medium, subangular blocky structure; very hard, friable; common fine roots; common clay films on ped faces; non-calcareous; abrupt boundary.
B225	38-51	Reddish brown (5YR 4/3) sandy clay laom; moderate medium subangular structure; very hard, friable; few fine roots; thin continuous clay films on ped faces; noncalcareous; abrupt boundary.
Cca	51-	Indurated and laminated impenetrable caliche layer.

TEST SITE: Double Lakes

SOIL: Brownfield

Horizon	Depth (cm)	Morphology
AP	0-25	Reddish brown (5YR 4/4) loamy sand, structureless, single grain; noncalcareous; clear smooth boundary.
A2	25-51	Dark reddish gray (5YR 4/2) sandy loam; weak, medium, granular and subangular blocky structure; noncalcareous; clear smooth boundary.
B21t	51-97	Dark reddish gray (5YR 4/2) light sandy clay loam; coarse weak prismatic breaking to moderate, medium, subangular blocky structure; very hard, friable; thin, nearly continuous clay films on ped faces; noncalcareous; clear wavy boundary.
B22t	97-122	Reddish brown (5YR 4/4) sandy clay loam; moderate and weak, medium, subangular blocky structure; very, hard, friable; thin patchy clay films; noncalcareous; gradual wavy boundary.
B23t	122-142	Yellowish red (5YR 5/6) sandy clay loam; moderate and weak, medium, subangular blocky structure; very hard, firm; thin patchy clay films; noncalcareous; clear wavy boundary.
B24tca	142-	Light reddish brown (5YR 6/3) sandy clay loam; moderate medium, subangular blocky structure; very hard, firm; common fine clay masses; 15 percent fine calcium carbonate both disseminated and as masses; extremely calcareous.

TEST SITE: Double Lakes

SOIL: Drake

Horizon	Depth (cm)	Morphology
AL	0-18	Dark yellowish brown (19YR 4/4) loam; weak medium granular structure; slightly hard; friable; common fine roots; calcareous; clear smooth boundary.
C1	18-91	Light gray (10YR 7/2) loam; very weak, fine, subangular blocky structure; hard, friable; few fine roots, calcareous; gradual wavy boundary.
C2	91-	Pale brown (10YR 6/3) loam; very weak, fine subangular blocky structure; hard, friable; calcareous.

TEST SITE: Double Lakes

SOIL: Portales

Horizon	Depth (cm)	Morphology
A1	0-18	Very dark grayish brown (10YR 3/2) loam, moist; weak, fine, granular structure; hard, friable; common fine roots; calcareous; clear wavy boundary.
B21	18-25	Very dark grayish brown (10YR 3/2) heavy loam; moderate, medium, subangular blocky structure; hard, friable; common fine roots; calcareous; clear wavy boundary.
B22	25-51	Brown (10YR 4/3) heavy loam; moderate and weak, medium subangular blocky structure; few fine roots; few fine masses of soft calcium carbonate; gradual wavy boundary.
B23ca	51-107	Brown (10YR 5/3) heavy loam; moderate and weak, medium, subangular blocky structure; hard, friable; finely disseminated calcium carbonate; extremely calcareous; gradual wavy boundary.
B24ca	107-164	Grayish brown (10YR 5/2) light clay loam; moderate and weak, medium, subangular blocky structure; finely dissominated calcium carbonate; extremely calcareous.

TEST SITE: Double Lakes

SOIL: Potter

Horizon	Depth (cm)	Morphology
A1	0-25	Brown (10YR 4/3) sandy clay loam; moderate, medium, granular structure; slightly hard, friable; many fine roots; five to fourty percent gravel cover and inclusion from 1/2 inch to 4 inches in diameter; calcareous; clear wavy boundary.
Cca	25-36	White (10YR 8/1) sandy clay loam; weak medium subangular blocky structure of soil between the gravel; few roots; greater than 40 percent calcium carbonate gravel to 12 inches in diameter; calcareous.

TEST SITE: Double Lakes

SOIL: Randall

Horizon	Depth (cm)	Morphology
A1	0-51	Dark gray (10YR 3/1) clay; weak coarse blocky structure breaking to fine blocky structure; extremely hard, very firm, very sticky; shiny pressure faces on peds; noncalcareous; diffuse wavy boundary.
AD	51-127	Gray (10YR 5/1) moderate fine and medium blocky structure; wedgeshaped parallelepiped; extremely hard, very firm, sticky; few fine brownish sploches in lower portion; weakly calcareous.

TEST SITE: Double Lakes

SOIL: Tivoli

Horizon	Depth (cm)	Morphology
A1	0-18	Brown (10YR 4/3) fine sand; single grain structureless; loose; very friable, common roots; noncalcareous; gradual smooth boundary.
C	18-152	Brownish yellow (10YR 6/6) fine sand, single grain, structureless; loose; very friable; noncalcareous.

TEST SITE: Double Lakes

SOIL: Zita

Horizon	Depth (cm)	Morphology
A1	0-25	Very dark grayish brown (10YR 3/2) loam; moderate, medium, subangular blocky and granular structure; hard, friable; common fine roots; noncalcareous; clear smooth boundary.
B1	25-66	Dark grayish brown (10YR 4/2) loam; moderate and weak, medium subangular blocky structure; hard, friable; common fine roots; calcareous; gradual wavy boundary.
B21	66-94	Grayish brown (2.5YR 5/2) loam; moderate and weak, medium, subangular blocky structure; hard, firm; few fine roots; calcareous; gradual wavy boundary.
B22	94-147	Light gray (2.5Y 7/2) loam; weak and moderate, medium, subangular blocky structure; hard, friable; few fine roots; calcareous; gradual wavy boundary.
B23	146-164	Light brownish gray (2.5Y 6/2) light clay loam; weak and moderate, medium, subangular blocky structure; calcareous.

APPENDIX B

LOGS OF DRILL HOLES AND POWER AUGER HOLES AT THE ERTS-1 TEST SITE

Hole #1

Depth	Description and Remarks
0-60 cm.	Dark brown clay
60-1.2 m.	Light gray brown clay
1.2-3.0	Light gray clay
3.0-3.3	Harder and redder
3.3-4.35	Light red brown w/ white blobs
4.35-5.3	Hard-sandy
5.3-5.7	Softer sand w/ some calcareous fragments lt. reddish brown to pink
5.7-7.8	Pink and white calcrete frags--thin soft zones (Note many indurated frags--impregnated fine sand)*(see sample VIII & VII)
7.8-8.85	Softer - still calcrete frags, 2-3mm grains of quartz brown "Joslsen" noted. Increase in percent of soft white to gray, "silty clay"
8.85-10	Ibid.
10-11.2	Soft loosing circulation
11.2-11.9	Kdc.

Hole #2

Depth	Description and Remarks
0-60 cm.	Black hard brown clay loam
60-1.8 m.	Greenish gray clay
1.8-2.4	Reddish brown sand
2.4-6	Light gray brown to greenish gray clay
6	Lost circulation

Hole #3

Depth	Description and Remarks
0-76 cm.	Sandy
76-3 m.	Gray clay hard at 10
3-5.3	Gray and white clay (partly lime impure)
5.3-6	Clay good sample recovery
6-7.8	Clay gray
7.8-8.3	Harder less sample recovery (sandy?)
8.3-11.1	Start using water
11.1	Hard thin zone
11.1-15	Sandy poor sample recovery
15-15.15	Harder zone
15.15-19.7	Gray-gray brown sandy clay?
19.7	Greenish gray

C-3

Hole #4

Depth	Description and Remarks
0-5.1 m.	Soil upper 5' sandy 5-17
5.1-6	Harder zone - sand w/ carb. impreg. sands not as cement
6-10.3	Softer, brown to pinkish sandy lime impreg. material - small sample recovery
10.3-15.8	Large chunks brown to pink sandy clay
15.8-16.25	Change harder - bit pluged marked decrease in sand, bit sample gray brown clay (10YR)

Hole #5

Depth	Description and Remarks
0-6.3 m.	Sandy - like 20-34 zone in 4
6.3-12.1	Sandy clay, 10YR 6.4-7.4 gray colors
12.1-16.5	Brown 7.5YR 5.4 mixed w/ pinkish gray 7.5YR 7.2 sandy clay
16.5-17.1	No sample recovery
17.1-17.5	Water
17.5-18.5	Water - bit sample lt. gray to pale yellow
18.5	5Y 7.2-7.3

Hole #6

Depth	Description and Remarks
0-60 cm.	Dark brown loam
60-1.2 m.	Gray clay
1.2-2.25	Gray sand
2.25-3.3	Gray sand w/ white carbonate
3.3-3.88	Light brown sand to clayey sand
3.88-5.1	Drills hard like above w/ white lime impregnated flakes
5.1-6	Softer like above
6-8.41	Light gray brown to light gray sandy clay, limy
8.41-10.5	Light brown to light gray sandy clay
10.5-12.6	Light gray to white w/ some brown sandy clay
12.6-16.5	Poor sample recovery - sandy, taking water at 52
16.5-17.8	Alternating hard and soft, sandy
17.8-22.7	Gray clay, 56Y 6/1-7/1 light greenish gray w/ some brown sandy clay, trace of calcrete frags and cherts
22.7-23.8	Hard no sample recovery
24.1-25.3	Color change to light olive, bit plugged K_{ki}

Hole #7

Depth	Description and Remarks
0-90 cm.	Dark brown clay loam
90-1.8 m.	Gray sandy loam to sandy clay loam
1.8-2.4	Light gray - carbonate impreg. sandy loam to sandy clay loam
2.4-3.88	Light gray brown fine sand
3.88	Lost circulation

Hole #8

Depth	Description and Remarks
0-60 cm.	Dark brown clay loam
60-2.1 m.	Gray brown sandy clay loam w/ white limy flecks
2.1-5.1	5YR to 5YR 7/3 reddish brown sandy clay loam or loam w/ white ca zone increasing downward hard at 17
5.1-8.1	7YR 6/3-5/4 softer same as above
8.1-15.6	Pink w/ some reddish brown sandy clay loam 5YR 5/1 7-4 27-30
15.6-18.1	Siliceous cherty sand, angular
18.1	Kdc

Hole #9

Depth	Description and Remarks
0-1.8 m.	Soil
1.8-2.7	Dune
2.7-3.6	5YR 4/4 sd
3.6-4.81	7.5YR 5/4 + 7/4 with caliche frag.
4.81-6.6	7.5YR 6/4
6.6-9.1	Cherty, brown 7.5YR 5/4
9.1-12.1	10YR 6/3
12.1-15.0	7.5YR 5/4 to 6/4
15.0-16.5	Sdy 7.5YR 5/4
16.5-17.8	7.5YR 5/4, 5YR limes also
17.8-18.7	Harder, takes water, a lot light caliche fragments
18.7-20.5	Sdy, 10YR 6/3, some 7.5YR 5/3
20.5-21.1	Same, grayer mud
21.1-22.7	Little return
22.7-27.3	Hard, few cuttings 10YR 5/3 with caliche

Hole #10

Depth	Description and Remarks
0-45 cm.	Clay loam 10YR 3/2
45-1.8 m.	Clay loam to sandy clay 10YR 6/2-5/2, some white caliche? frags - strongly calcareous
1.8-4.2	Sandy clay loam 10YR 6/3 calcareous w/ trace 7.5YR 5/4 and cherty sandy
4.2-6.5	Sandy clay - calcareous, some brown sandy clay loam frags of 10YR 5/6 (yellow brown) bit sample 10YR 6/3 sandy clay loam, rex w/ KCl strongly

Hole #11

Depth	Description and Remarks
0-30 cm.	10YR 3/2 clay loam
30-76	10YR 6/2
76-1.05 m.	10YR 4/2-5/2
1.05-9.1	2.5Y 6/2 sandy clay loam, sandy clay shell frags at 10', gypsum xls, (small sand-sized) at 12' 2.5Y 5/2 trace calcareous to 30
9.1-9.8	5Y 6/1-5/1 calcareous scl and sc
9.8-10.04	10YR 5/4 sandy clay, sandy clay loam w/ trace 7/5YR 5/4 blebs and calcrete frags
10.04-11.5	7.5YR 6/2 light brown sandy clay-scl, coarse silicious sand some white frags
11.5-14.8	Large gypsum xls, 2.5Y 6/2 (some 5Y 6/2) and 7.5YR 6/4 sandy clay - sandy clay loam
14.8-15.0	Softer drilling clay w/o gyp.
15.0-17.1	Like 38-49.0
17.1-18.7	Sandy - loosing circulation
18.7-20.5	Mud turned green K_{ki}
20.5	Clay - dark gray to black K_{ki}

Hole #12

Depth	Description and Remarks
60-90 cm.	10YR 4/2 clay to clay loam
90-1.2 m.	10YR 8/1 and 7/1 and 7/2 clay to clay loam mud color change dark and light gray
1.2-2.7	10YR 8/1 clay (marly)
2.7-3	Mud color change light gray to light green
3-3.88	5Y 8/1 and 2.5Y 6/2 (marly) clay
3.88-4.5	As above w/ some brown (7.5YR) blebs mud color change browner at 15
4.5-6.6	Sandy 10YR 6/3 hard frags 7.5YR 6/4-5/4 blebs poor sample recovery browner unit
6.6-7.8	Harder - mud color change to pink, redder cuttings 7.5YR 6/4-5/4
7.8-10	7.5YR 5/4 w/ some 4/4, pink to white and brown calcrete w/ some cherty frags. alternating hard and soft drilling
10-10.3	Top of K?, mud yellower
10.3-10.7	Dark Creek bit sample

Hole #13

Depth	Description and Remarks
0-30 cm.	10YR 3/2 clay and clay loam
30-1.8 m.	5Y 6/1-7/1 clay
1.8-3.0	5Y 7/1-8/1 clay
3.0-3.88	5Y 8/1 clay
3.88-4.81	5Y 6/2-5/2 sandy loam to sandy clay loam
4.81-6.8	Lost circulation, some sand 2.5Y 7/2 with above material

Hole #14

Depth	Description and Remarks
0-60 cm.	10YR 2/2 clay loam
60-1.5 m.	10YR 4/2-5/2 clay loam
1.5-2.1	10YR 6/2 and 7/ clay loam - some calcrete frags. 10YR 7/3 5-6 drill bounced
2.1-3.3	10YR 7/2 and 8/1 sand and sandy loam, calcrete frags.
4.5-6.3	7.5YR 5/4 and 6/2 sandy loam
6.3-7.57	7.5YR 5/4 sandy loam w/ 7.5YR 7/2 sandy loam some calcrete frags.
7.57-8.41	As above 10YR 7/2 (calcrete fragss)
8.41-9.4	Alternating hard and soft 7.5YR and 10YR 7/2 w/ trace 10YR 7/6 and 6/6 hard frags. some sandy loam
9.4-10	As above, more 10YR 5/6, 6/6, and 7/6
10-10.8	As above, trace 7.5 6/8 frags.
10.8-12	Shale soft 5Y 5/2 and 5/3, bit sample yellowish green sandy clay (Kdc)

Hole #15

Depth	Description and Remarks
0-1.05 m.	7.5YR 4/2 sandy loam
1.05-1.65	10YR 4/2-5/2 sandy loam w/ some calcrete frags. 10YR 8/2
1.65-3	7.5YR 5/4-4/4, sandy loam to sandy clay loam, some calcrete frags.
3-3.6	Fine sand 10YR 5/2, mixed w/ above trace 5Y 6/3 shale frags.
3.6-5.3	Ditto, 5Y 6/3

Hole #16

Depth	Description and Remarks
0-1.2 m	10YR 3/2 clay loam, weakly calcareous
1.2-1.8	7.5YR 3/2 clay loam, with white siliceous calcrete frags.
1.85-3	10YR 6/2 and 7/1 sandy clay loam and clay w/ 2.5Y frags, soft and hard caliche frags trace mollusca frags.
3-4.2	10YR 6/2 sandy clay loams to clay w/ increasing 2.5Y 5/2 clay frags. and caliche frags.
4.2-5.1	Fine sand 10YR 6/2, w/ caliche frags.
5.1-6.9	Ditto bit sample 2.5YR 6/2 sandy clay to 10YR

Hole #17

Depth	Description and Remarks
0-30 cm.	10YR 4/2 loam to clay loam
30-60	10YR 7/2 clay
10-1.2 m.	2.5Y 6/2 clay
1.2-2.56	10YR 7/2 and 2.5Y 6/2 clay sandy clay harder w/ 5-7 and 7.8
2.56-4.2	10YR 8/4 and 1-YR 7/3 calcrete - sandy w/ minor 10YR 7/2 - 7.5YR 3/2
4.2-5.1	2.5Y 6/2 sand 2.5Y 6/6 (siliceous rock frags.) bit sample 2.5Y 6/2 and 6/4

Hole #18

Depth	Description and Remarks
0-60 cm.	10YR 3/2 clay loam noncalcareous
60-1.5 m.	7.5YR 4/2 and 4/4 calcareous clay loam, some white to pink carbonate impreg.
1.5-10	7.5YR 6/4 and 7/4 clay to sandy caly loam some 7/5YR 8/4 calcrete frags.
10-12.5	Hard dense calcrete frags 7.5YR 7/4 and 8/4 with some 7.5 6/4-7/4 sandy loam to sandy clay loam.
12.5-18.1	7.5YR 6/4 and 7/2 sand clay loam w/ 7.5YR 7/2 and 8/4 calcrete frags.
18.1-19.5	Sandy loam to sandy clay loam 7.5YR 3/4-6/4 and 2.5Y 6/2
19.5-21	7.5Y 6/4 fine sandy loam some 10YR
21-22	Trace greenish shale, frags 2.5Y-5Y 3/2 and 6/2 hard yellowish brown 10YR 5/6 chips Kdc

Hole #19

Depth	Description and Remarks
0-30 cm.	10YR 3/2 clay
30-60	10YR 4/2 clay
60-2.1 m.	10YR 5-2-6-2 clay and sandy clay
2.1-4.95	7.5YR 6/4 sandy clay loam, w/ hard pink calcrete frags 7.5YR-10YR 6/3 fine sand
4.95-5.42	2.5Y to 10YR 7/2 and 5Y 7/2 clay, trace 5YR 6/4 blebs
5.42-6.8	No sample recovery - sandy
6.8-10.05	Split spoon sample 22.5-23 10YR 6/3 sandy clay loam, Rex w/ KCl strongly some tubular pore w/ black coating 23-23.5 10YR 6/4-7/4 loamy sand, very coarse grains mixed mineralogy mainly quartz, Rex w/ HCl strongly

Hole #20

Depth	Description and Remarks
0-1.2 m.	10YR 3/2-4/2 clay to clay loam Rex HCl
1.2-2.4	10YR 5/2 and 6/2 some 2.5Y 5/2 clay Rex HCl
2.4-3.15	2.5Y 6/2-7/2 clay Rex HCl soft and hard drilling
3.15-3.3	2.5Y 5/2 and 6/4 clay
3.3-3.72	10YR 5/2-5/4 clay to sandy clay some 7.5YR 5/4 blebs
3.72-4.2	7.5YR 5/4, clay w/ some 10YR and 2.5Y 7.5YR 6/4 streaks and pink calcrete frags.
4.2-4.5	7.5YR 7/2 and 8/2 to 10YR soft caliche, clay loam
4.5-7.57	7.5YR 7/2 and 8/2 w/ some 6/4 blebs, clay some sandy zones
7.57-9.4	7.5YR 6/4 and 8/2 sandy clay loam
9.4-10.3	10YR 7/2 sandy clay loam
10.3-11.75	7.5YR 7/2 and 10YR 7/2-6/3 sandy clay loam
11.75-14.8	10YR and 2/5Y 6/2 sandy clay to sandy clay loam
14.8-17.8	10YR 7/2 and 6/2 sandy clay loam
17.1-17.8	Lost circulation
17.8	K

Hole #21

Depth	Description and Remarks
0-45 cm.	10YR 7.5YR 2/2 sandy clay loam noncalcareous
45-1.05 m.	7.5YR 4/4 to 5YR 4/4 sandy clay loam
1.05-2.1	5YR 5/4-6/4 and 7/5YR 7/4 sandy clay loam caliche frags (5-7) hard and soft drilling
2.1-3.6	7.5YR 7/4 lime impreg. sandy clay loam and sandy loam with some fine sand 7.5YR 5/4-6/4 and 10YR 5/3
3.6-9.1	10YR 6/4 to 7.5YR 6/4 and 5/4 lime impreg. sandy clay loam to sandy clay some fine sand 10YR 6/4
9.1-9.7	7.5YR 5/4 and 6/4 sandy clay loam some calcrete frags 7.5YR 7/4 to 8/4
9.7-13.9	At 32 selenite x/x and 10YR lenes 7.5YR 5/4 to 6/4 sandy clay loam
13.9-16.9	10YR 7/3 to 6/3 lime impreg. sandy clay loam
16.9-17.8	10YR and 7.5YR 6/4 sandy clay loam to sandy loam w/ trace 5YR 5/6 shale frags.
17.8-18.7	7.5YR 6/4 sandy clay loam to sandy loam coarse sand, siliceous gravel and calcrete frags.
18.7-20.2	10YR 7/3 sandy loam mixed w/ above
20.2-23	10YR 8/2 sand poor sample recovery bit sample 10YR 6/3 sandy clay soft caliche

Hole #22

Depth	Description and Remarks
0-90 cm.	10YR 2/2 10YR 3/2 clay loam clay, calcareous
90-1.8 m.	10YR 4/2 10YR 5/2 sandy clay, calcareous, scattered nodules
1.8-2.7	10YR 5/2-10YR 6/2 sandy clay
2.7-6	10YR 6/2-7/2 sandy clay to clay, some sand stringers 10YR 7/3, gyp Xls
6-7.57	2.5Y-10YR 7/2 sandy clay, some calcrete frags. typ. selenite Xls, fine sand streaks
7.57-10	10YR-2.5Y 7/1 and 8/1 sandy clay some coarse sand and very fine pebble size selenite Xls
10-13	2.5Y 4/0 and 5/4 clay and sandy clay, large gyp. Xls.
13	5Y 2/2 clay

Hole #24

Depth	Description and Remarks
0-15 cm.	2.5Y 5/4 sandy clay loam, salt and selenite crystals $NaSO_4$ blebs
15-60	2.5Y 5/6 to 6/6 sandy clay loam some 2.5Y 6/8 and 10YR 5/1 sandy clay streamers
10-76	Gup sand zone 2.5Y 5/4 clay, xls 1/4-1/2" in size water zone
76-1.5 m.	Black clay loam, gyp. xls, some streamers of 2.5Y 4/3
1.5-1.8	7.5 Gy 3/1 clay loam, gyp. xls some gyp sand zones
1.8-2.4	Black clay loam large gyp xls > 1"
2.4-2.56	2.5Y 6/8 clay
2.56-3.15	5Y 7/8 and 7.5Gy 3/1 clay
3.15	2Gy 3/1 clay K_{ki}

Hole #25

Depth	Description and Remarks
0-45 cm.	Sandy clay loam, organic material, recent surface debris
45-60	Gyp. sand zone, water zone
60-76	2.5Y 5/4 and 6/8 to 5Y 2/1 clay loam
76-1.2 m.	5Y 2/1 clay gyp. xls
1.2-1.5	7.5Gy 4/1 clay
1.5-3 m.	5Y 2/1 clay large gyp. xls at 6'
3	2 Gy 3/1 clam shell cants. Kki

Hole #26

Depth	Description and Remarks
0-45 cm.	Sand to sandy clay loam
39-1.05 m.	5Y 2/1 clay loam w/ gyp. xls and yellow oxidized streamers
1.05-1.2	7.5YR 5/8 clay loam w/ gyp. xls
1.2-1.35	5YR 4/3 mottled 7.5YR 5/8 sandy clay
1.35-1.8	7.5YR 3/1 mottled 7.5YR 5/8 sandy clay
1.8-2.56	5Y 4/4 clay loam w/ gyp. xls
2.56	2Gy 3/1 clay

Hole #27

Depth	Description and Remarks
0-45 cm.	2.5Y 5/4 sandy clay loam and gypsum
45-1.2 m.	7.5GY 5/1 clay loam some streaks of 2.5YV 5/8 sandy clay
1.2-1.63	7.5GY 7/1 to black sandy clay loam some red clay streaks
1.63-2.7	black shale increase in gyp. xls some up to 1"
2.7-2.88	Black shale w/ pyrite xls and less gyp. than above
2.88-3	Black shale increase gypsum
3	2.5Gy 3/1 Kki hard zone

Hole #28

Depth	Description and Remarks
0-60 cm.	Surface (Recent sandy clay)
60-1.05 m.	Gypsiferious clayey sand up to gravel in size and appearance 2.5Y 6/8 mottled w/ 7.5YR 5/6
1.05-2.25	5B 5/1 sandy clay w/ gyp. xls
2.25-4.2	5G 5/1 sandy clay - some sans streamers
4.2-4.95	7.5Gy 4/1 and 3/1 clay mixed with black clay gypsum xls present
4.95-5.3	Black clay w/ pyrite
5.3-5.7	Black clay w/ gypsum
5.7-5.9	2.5Gy 3/1 Kki? hard zone

Hole #D 4

Depth	Description and Remarks
45 cm.	Silt, fine sandy, slightly clayey, limy, slightly organic, firm, brown, ML
1.11 m.	Silt, same, w/ caliche nodules, tan and white, ML
1.8	Caliche, silty, slightly clayey, moderately hard, crumbly, white, CAL
3	Sand, fine, silty, limy, trace clay, few caliche nodules (-2"), moderately hard, slightly consolidated, reddish-brown, dry, SM
6	
7.3	Clay, fine sandy, silty, hard limy nodules, slightly compact, moderately plastic (if wet), brown w/ white, dry, CL
8.1	
9.1	Caliche, silty, some fine sand, slightly clayey in part, slightly compact, and layers of sand, fine, silty, some caliche, weakly cemented, moderately hard w/ hard caliche nodules and seams (-3"), tan and white, CAL
12.1	Sand, fine, silty, some caliche, hard caliche nodules (-2"), weakly to moderately cemented 44.5-46', moderately hard w/ hard cemented layer 44-44.5', tan, and white, SM
15	Sand, silty, some caliche, moderately consolidated, brown, SM

18.1	Silt, fine sandy, slightly clayey to clayey in part, moderately consolidated and layers of clay, silty, moderately plastic, still, brown, ML
22.7	Clay, silty, some fine sand, limy, moderately plastic stiff, brown, CL
24.1	Sand, fine, silty, slightly clayey, slightly cemented, firm, brown, SM
25.2	Siltstone, clayey, shaley moderately hard, yellow and brown

Hole #D 5

Depth	Description and Remarks
45 cm.	Silt, fine sandy, slightly clayey, slightly organic, trace plasticity, firm, light brown, dry, ML-SM
1.8 m.	Clay, silty, limy, gypt, fine sandy, much fine sand in part, few gypsum nodules 16-18', slightly to moderately plastic 16-18', granular porous, firm, tan, dry, CL-ML
5.42	Sand, fine, silty, trace clay, limy, firm, tan, dry, SM
6.3	Clay, silty, fine sandy, limy, gypy 21-22.5', slightly to moderately plastic 22.5-25', firm to soft 22.5-30', white and brown, porous 21-22.5', CL
9.1	Sand, fine, little medium, silty to slightly silty 35.5-38', slightly clayey 34-35.5', few fine roots, soft, tan and brown, SM
11.5	Clay, silty, fine sandy, limy, some decayed fine roots, moderately plastic, sticky, soft, brown and tan, CL
12.6	Sand, fine, silty, slightly clayey 40.5-44.5', soft to firm 46.5-47', 47.5-48', slightly plastic in part, brown, SM-SC
14.5	Clay, silty, some fine sand, w/ silty sand in thin layers 56-59', soft, moderately plastic, sticky in part, greenish-gray to dark brown and tan, CL

17.8	Sand, fine to medium (quartz and gypsum), silty in part w/ thin clay seams, firm, tan, SM

Hole #D 6

Depth	Description and Remarks
60 cm.	Clay, silty, much fine sand, fine roots, slightly organic, moderately plastic, firm, black, slightly moist, CL
90	Clay, silty, limy, very limy nodules (-1/2"), moderately to slightly plastic 4-5', firm, tan and white, slightly moist, dry 4-5', CL
1.5 m.	Cavity or soft silt
2.32	Clay, silty, some fine sand, many limy nodules (-1/4", few -1/2"), moderately plastic, soft, granular, tan and white; trace organic material, CL
3.88	Clay, much fine sand, silty, limy and caliche nodules (-3/8"), moderately plastic, tough, slightly cemented irregular seams, granular, brown w/ black stain; some fine pores, CL
7.3	Sand, fine, silty, slightly clayey, in part silt, slightly clayey, fine sandy, few limy nodules (-3/8"), moderately hard, moderately consolidated, brown w/ black staines; fine pores, crumbles easily, SM-ML
9.5	Clay, silty, some fine sand, few caliche nodules (-3/8"), slightly plastic, moderately hard, w/ few cemented thin seams, CL
10.8	Sand, fine, silty, limy, slightly clayey in part, limy nodules (-1/4"), moderately hard, moderately consolidated, slightly

	cemented and blocky in thin layers, tan and pink w/ black stains; fine pores, SM
12.6	Clay, silty, some fine sand, much fine sand in part, limy nodules (-3/8"), many 41-42', moderately compact, thin weakly cemented veinlets, slightly plastic in part, brown w/ black stains, CL
15	Sand, silty, limy, slightly gravelly in part, weakly to moderately cemented layers 48.5-49', 50.5-51', tan and pink, SM
15.8	Clay, silty, bentonitic (?), some fine sand, very limy in part, moderately plastic, tough, white and brown, CL
16.4	Sand, small amount of gravel, slightly to moderately cemented, moderately hard, tan, SP
17.1	Shale, clayey, few silty seams, few fossils, compact, laminated, yellow-brown
17.70	Limestone, chalky, shaly seams, broken, moderately hard, tan
18.7	Shale, clayey, thin silty seams w/ fossils, laminated to massive, compact, moderately hard, brown w/ yellow Fe nodules; few 30-60° joints, slickensided; feels greasy
22	Shale, clayey, silty in fine seams, few fossils and Fe nodules, compact, laminated, moderately hard, black, 30-60° slickensided joints; feels greasy

APPENDIX C

LOGS OF CORE HOLES AT TEST SITE

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CORE HOLE - DOUBLE LAKES TEST SITE

Depth in Meters	Lithology
0.0 - 0.3	Soil
0.3 - 1.5	Sandy loam, light gray to dull yellow orange (10YR 8/ -7/2)
1.5 - 2.4	Sandy loam to loam, dull yellow orange (10YR 7/2), calcareous, gypsiferous & soluable salt threads
2.4 - 3.0	Sandy loam, dull yellow orange (10YR 7/2) calcareous and gypsiferous, dark minerals (MnO?)
3.0 - 4.2	Loam, dull yellow orange (10YR 7/2) with streak of grayish-yellow (2.5YR 7/2), calcareous with threads of gypsum
4.2 - 4.8	As above with introduction of carbonaceous particles
4.8 - 6.7	Sandy clay, dull yellow orange (10YR 7/2) calcareous with threads of gypsum
6.7 - 6.8	Clay, brownish gray (10YR 4/1)
6.8 - 8.3	Sandy clay, light gray (10YR 7/1), threads of gypsum and small pieces of charcoal.
8.3 - 8.4	Clay, brownish gray (10 YR 4/1)
8.4 - 8.6	Sandy clay, grayed yellow brown (10YR 6/2) with threads of gypsum
8.6 - 8.8	Clay loam, grayish yellow brown (10YR 6/2) abundant small gypsum crystals
8.8 -10.0	Sandy clay loam, dull yellow orange (10YR 7/2), few strings of gypsum
10.0-10.3	Clay, grayish-yellow (2.5Y 7/2), some gypsum and fine carbonate concretions

10.3-10.5	Fine sand, light gray (2.5Y 8/2) (very clean sand)
10.5-10.15	Clay loam, grayish-yellow (2.5Y 7/2)
10.15-10.20	Sandy loam, grayish-yellow (2.5Y 7/2) some orange mottling
10.20-10.25	Sandy clay loam, light gray (10YR 7/1) some orange mottling
10.25-15.0	Clay, gray (N/4-N/6)
15.0-16.0	Clay, gray to olive gray (N/5-5GY 5/1) increasing from top to bottom in fine sand content
16.0-16.5	Fine sandy loam, olive gray to dark olive gray (5GY 5/1-4/1) with common black organic or MnO zones and gypsum rosettes
16.5-17.0	Clay, light olive gray (5GY 7/1), common gypsum crystals, black zones and plant fibers
16.0-22.0	Clay, greenish-gray to dark, greenish-gray (5G6/1-4/1) varying size and abundance of gypsum crystals
22.0-22.50	Clay, brownish-black to olive black (5Y 4/1-3/1) layers of abundant gypsum crystals
22.5-23.0	Clay (shale?), black (5Y 2/1) with some gypsum crystals

APPENDIX D

CLAY MINERALOGY - CORE HOLE, DOUBLE LAKES TEST SITE

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Depth	Clay Minerals[1]	Carbonate[2] Content
0-7.6	S-poorly crystalline I-SM	D-very high
7.6-8.8	I-SM-poorly crystalline	D-very high
8.8-9.75	I,S,K,SM(?)	D-very high
9.75-10.0	I,S-poorly crystalline	D-C-very high
10.0-11.0	I,SM,S,P(?)	D-very high
11.0-11.9	S,I,K,SM	D-very high
11.9-13.4	I,S,K,SM	D-very high
13.4-13.7	S,I,K,SM	D-very high
13.7-16.2	I,K,SM,S	D-low
16.2-17.4	I,K,P	D-C-low
17.4-18.4	I=K,SM	D-high
18.4-20.3	I,K,I-SM,S	D-very low
20.3-21.7	I,K,S=SM	D-high
21.7-22.0	I,S(?)	D-high
22.0-22.9	SM,K,I	none
22.9-	SM,K,I	none

1 Clay minerals are listed in order of magnitude

2 Carbonate content in the clay fraction

I = Illite, S = Sepiolite, SM = Smectite, K = Kaolinite, P = Polygorskite, D = Dolomite, C = Calcite, I-SM-Interstratified

APPENDIX E

PRECIPITATION RECORDS

DATE		T-BAR	DOUBLE LAKES	INTENSITY
Sept 5	1972	2.10		1 1/2-hr heavy storm
Sept 15		0.75		2 1/2-hr rain
Oct 19-22		2.40		20-hr intermittent rain
Oct 25-27		0.55		8-hr intermittent rain
Nov 13		0.05		1-hr light rain
Nov 18		0.15		2 1/2-hr rain
Nov 24-25		0.05		2-hr light rain & snow
Nov 29-30		0.05		light snow
Dec 29-30		0.10		1 1/2-hr
Jan 3	1973	0.10	0.15	1-hr shower
Jan 4-9		?	0.10+	drizzle, freezing drizzle & snow
Jan 9-12			0.25	freezing drizzle & snow
Jan 21		0.60	No Data	5-hr
Jan 25-26		0.40	No Data	3-hr snow
Feb 8-9		0.65	0.65	6-hr snow
Feb 17-18		0.15		1-hr snow
Feb 21-23		0.65	0.70	5-hr snow
Feb 28-Mar 3		NO DATA		
Mar 4		0.05		1/2-hr shower
Mar 10		1.00	1.00	4-hr rain
Mar 13-Apr 3		NO DATA		
Apr 25-26		0.35	No Data	3-hr rain
May 9-12		0.15	0.05	1-hr shower
May 13-15		0.30	0.55	12-hr light rain
May 22		1.20	No Data	
June 2			0.25	1/2-hr shower
June 14		0.55	0.20	1 1/2-hr rain
July 10			1.00	3/4-hr heavy storm
July 18			0.25	1 3/4-hr rain
July 20			0.02	light shower
July 21-31			1.25	9-hr rain
Aug 16			0.05	20-min light shower

APPENDIX F

DAILY MINIMUM AND MAXIMUM TEMPERATURES AT TEST SITE

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TABLE A - T-BAR

DATE	MON		TUES		WED		THURS		FRI		SAT		SUN	
9-2-72												64	62	71
9-4	67	81	69	77	70	87	66	88	67	85	66	84	66	85
9-11	64	84	66	85	67	84	65	84	66	85	64	90	65	86
9-18	67	--	--	85	69	84	61	69	45	71	46	81	60	85
9-25	63	85	59	80	53	84	63	89	64	86	40	74	43	84
10-2	50	80	50	80	52	80	50	84	53	69	45	74	53	87
10-9	54	90	59	87	60	83	54	82	54	86	59	87	57	75
10-16	56	91	54	90	60	73	37	54	37	48	48	60	46	66
10-23	42	62	42	56	47	56	46	57	44	72	52	68	47	74
10-30	60	73	35	40	30	57	33	63	33	68	34	71	42	73
11-6	53	70	40	64	40	66	46	66	34	62	39	65	46	70
11-13	40	54	28	50	31	46	32	60	34	40	39	52	32	49
11-20	28	34	34	35	26	48	24	42	35	54	35	50	23	68
11-27	31	54	24	45	27	38	28	53	31	69	32	73	34	60
12-4	26	54	27	73	12	30	20	46	34	58	31	44	22	23
12-11	22	26	26	48	30	49	30	38	22	42	12	50	19	51
12-18	36	60	31	64	39	63	39	58	28	71	--	--	--	--
12-25	--	--	--	--	--	--	--	64	35	64	31	52	24	53
1-1-73	32	40	30	32	28	50	--	--	--	--	--	--	--	--
1-8	--	--	--	16	14	24	8	30	10	44	31	56	26	64
1-15	30	66	32	67	40	66	43	63	28	68	33	63	34	50
1-22	26	48	20	48	19	54	35	38	32	53	36	42	25	41
1-29	21	67	27	62	33	55	36	52	22	54	17	62	32	76

DATE	MON	TUES	WED	THURS	FRI	SAT	SUN
2-5	37 74	28 65	44 56	22 26	25 35	20 50	34 51
2-12	38 61	37 50	24 49	28 48	26 41	31 35	28 56
2-19	32 48	22 46	36 44	33 38	26 44	31 61	30 71
2-26	42 62	32 57	45 62	-- --	-- --	-- 67	32 61
3-5	42 72	41 64	26 72	43 68	43 55	44 47	38 66
3-12	39 70	-- 58	43 66	40 56	32 61	36 74	40 70
3-19	47 61	36 63	36 70	34 71	-- --	-- --	-- --
3-26	-- --	-- --	-- --	-- --	-- --	-- --	-- --
4-2	-- --	-- 50	34 52	26 59	30 64	34 72	29 42
4-9	20 52	21 64	34 68	39 74	49 78	60 79	64 76
4-16	38 65	48 74	43 81	48 77	42 80	45 80	49 80
4-23	44 74	44 72	52 64	45 55	33 64	41 80	53 84
4-30	60 82	47 75	34 --	32 72	42 78	56 69	58 74
5-7	52 78	48 87	51 91	53 95	60 91	54 68	50 58
5-14	50 55	41 69	48 84	47 82	54 91	54 98	63 92
5-21	56 94	61 80	54 86	59 89	56 89	59 89	52 75
5-28	53 75	43 82	51 88	57 76	55 87	63 86	50 86
6-4	57 90	57 82	46 87	54 89	52 88	51 80	54 81
6-11	63 84	55 84	59 86	63 89	-- 94	69 92	58 96
6-18	65 98	53 80	44 83	46 85	51 89	55 87	56 88
6-25	58 90	60 92	61 93	70 94	70		

TABLE B - DOUBLE LAKES

DATE	MON	TUES	WED	THURS	FRI	SAT	SUN
12-28-72				-- 65	37 64	30 52	27 53
1-1-73	30 38	29 31	25 --	-- --	-- --	-- --	-- --
1-8	-- --	-- 16	12 21	7 30	11 44	29 54	29 65
1-15	33 66	35 67	38 66	43 64	31 68	37 61	33 51
1-22	30 48	20 49	22 55	34 38	29 52	34 41	22 42
1-29	22 --	-- 61	32 56	36 53	27 56	22 62	33 78
2-5	38 75	31 63	44 56	20 25	22 36	22 50	32 50
2-12	37 63	34 50	24 50	29 48	27 40	30 34	27 56
2-19	30 52	26 51	39 43	32 37	23 44	30 61	31 72
2-26	40 --	-- --	-- --	-- --	-- --	-- 66	28 58
3-5	40 74	41 66	30 72	46 68	44 54	42 --	-- --
3-12	-- --	-- --	-- --	-- --	-- --	-- --	-- --
3-19	-- --	-- --	-- --	-- --	-- --	-- --	-- --
3-26	-- --	-- --	-- --	-- --	-- --	-- --	-- --
4-2	-- --	-- 50	34 52	28 59	31 65	36 72	27 41
4-9	21 50	24 64	34 69	41 75	50 78	60 80	62 74
4-16	39 66	46 76	46 82	49 78	42 81	45 80	52 80
4-23	50 76	46 78	50 63	46 54	34 64	40 82	53 86
4-30	59 33	48 --	-- 66	34 71	40 77	55 70	57 72
5-7	50 78	48 88	51 91	52 96	58 90	54 68	49 56
5-14	49 54	42 68	47 85	48 83	54 92	55 99	64 92
5-21	58 95	61 80	53 --	-- 89	53 88	59 89	51 74
5-28	52 75	42 82	52 89	56 75	56 87	62 85	50 86

DATE	MON		TUES		WED		THURS		FRI		SAT		SUN	
6-4-73	55	90	56	82	49	88	--	90	55	91	54	82	56	82
6-11	61	85	57	86	60	88	61	--	--	97	68	94	56	98
6-18	62	100	56	80	41	84	46	86	52	90	56	88	56	90
6-25	59	90	58	94	62	93	69	94	68	102	64	94	66	95
7-2	63	95	62	93	64	96	64	98	62	98	62	96	62	93
7-9	61	91	64	89	62	84	64	78	66	86	66	80	60	82
7-16	60	85	63	85	65	84	68	94	67	98	68	82	60	86
7-23	66	90	66	90	64	90	61	76	61	89	--	--	--	--
7-30	--	--	--	--	--	--	--	--	--	--	--	--	--	--
8-6	--	--	--	94	69	91	62	91	62	90	62	91	60	91
8-13	62	93	63	95	67	98	60	94	56	94	60	90	58	90
8-20	62	90	60	93	60	96	59	101	56	101	56	92	57	96
8-27	56	87	58											

APPENDIX G

SOIL MOISTURE DATA FROM NEUTRON PROBES

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TABLE A

T-BAR PLAYA TEST SITE

DATE	STATIONS	% BY VOLUME AT VARIOUS DEPTHS 6"	12"	24"	36"	48"	60"	TOTAL INCHES IN PROFILE
9-05-72	Station 2	28.77	36.73	36.43	39.38	42.03	41.27	23.0232
	3	26.26	32.02	33.97	38.86	37.50	37.70	21.0204
	4	27.77	32.82	33.78	-	-	-	7.6890
9-09-72	2	30.93	36.79	37.01	39.36	41.94	40.87	23.1648
	3	26.69	30.76	32.50	34.54	36.51	36.60	20.2650
	4	27.19	32.37	34.99	-	-	-	7.7724
9-15-72	2	30.46	35.35	34.95	36.50	38.57	39.75	21.9210
	3	22.38	28.29	29.84	32.15	34.89	34.47	18.8022
	4	29.13	30.05	31.49	-	-	-	7.3296
	1	35.33	43.75	43.01	41.42	28.87	35.33	22.5904
9-19-72	1	30.53	41.48	41.82	41.40	28.29	34.00	21.7818
	2	25.82	34.15	34.30	37.97	38.47	38.93	21.5586
	3	17.88	27.98	29.01	31.63	34.88	34.54	18.3588
	4	20.56	28.66	31.00	-	-	-	6.6732
9-26-72	1	28.46	41.04	39.80	38.47	25.85	-	16.6644
	2	20.88	30.08	32.96	34.94	37.05	37.16	20.1108
	3	15.54	25.93	28.97	30.31	33.33	32.20	17.4654
	4	19.25	26.45	29.67	-	-	-	6.3024
10-03-72	1	22.40	37.31	39.34	39.50	25.23	30.99	19.7898
	2	13.84	27.23	32.34	33.88	36.73	36.96	19.2534
	3	9.75	22.01	27.16	29.57	31.30	32.42	16.3596
	4	13.97	22.35	27.60	-	-	-	5.4912
10-10-72	1	16.56	35.40	39.14	40.40	26.18	31.85	19.6260
	2	8.74	21.17	31.97	32.63	36.42	36.61	18.3102
	3	8.78	20.67	26.03	28.86	31.58	32.56	16.0506
	4	12.52	20.59	26.01	-	-	-	5.1078

T-BAR PLAYA TEST SITE

DATE	STATIONS	% BY VOLUME AT VARIOUS DEPTHS 6"	12"	24"	36"	48"	60"	TOTAL INCHES IN PROFILE
11-28-72	Station 1	20.69	40.54	39.61	40.18	23.66	28.46	20.0430
	2	25.45	33.32	35.77	40.43	41.36	36.01	21.9546
	3	20.31	26.87	27.52	29.28	31.35	30.26	17.0400
	4	18.05	26.36	27.93	-	-	-	6.0162
12-05-72	1	29.71	39.71	38.05	38.52	21.73	27.20	19.2252
	2	21.71	31.45	34.75	32.94	36.05	35.97	19.9548
	3	18.64	25.79	27.21	29.42	30.73	30.46	16.8042
	4	20.00	26.15	27.95	-	-	-	6.1230
12-13-72	1	25.28	38.77	38.07	39.07	23.38	27.09	19.1562
	2	24.85	32.68	34.34	33.94	36.28	37.28	20.4726
	3	20.12	25.84	27.23	29.90	31.87	30.45	17.0916
	4	16.62	23.62	24.40	-	-	-	5.3424
1-20-73	1	45.19	49.84	47.87	45.47	27.60	33.83	24.2742
	2	31.89	37.68	37.28	36.65	39.38	40.06	22.5786
	3	37.73	41.72	41.20	43.54	45.19	44.28	25.6722
	4	32.63	34.11	34.57	-	-	-	8.1528
1-24-73	1	42.12	47.35	44.37	44.56	26.55	30.17	22.8462
	2	33.75	39.80	37.86	38.17	38.49	39.88	22.9410
	3	26.49	32.27	31.91	31.90	33.53	32.70	19.1304
	4	28.24	31.67	31.85	-	-	-	7.1466
1-27-73	1	40.71	45.42	41.64	42.68	25.43	29.54	21.8826
	2	28.75	38.48	38.05	36.86	38.10	37.95	22.1490
	3	28.79	35.33	34.17	32.84	34.77	33.94	20.1336
	4	30.17	34.17	31.70	-	-	-	7.6644

T-BAR PLAYA TEST SITE

DATE	STATIONS	% BY VOLUME AT VARIOUS DEPTHS 6"	12"	24"	36"	48"	60"	TOTAL INCHES IN PROFILE
1-30-73	Station 1	40.22	46.21	42.60	43.18	24.93	29.73	22.0386
	2	28.31	39.33	39.10	38.57	40.97	39.72	23.0616
	3	28.26	33.82	33.21	33.78	35.14	33.99	20.0592
	4	27.12	33.31	34.04	-	-	-	7.7106
2-01-73	1	40.66	45.49	43.15	40.98	23.80	29.33	21.6402
	2	34.60	41.01	39.59	41.80	42.58	41.78	24.4266
	3	32.37	36.23	35.20	35.99	37.36	36.27	21.4884
	4	32.96	35.79	35.76	-	-	-	8.4162
2-03-73	1	43.88	49.67	46.61	46.90	27.30	32.51	24.0114
	2	34.35	40.24	40.21	41.11	42.73	41.81	24.3786
	3	31.87	35.08	35.12	36.13	37.44	36.71	21.4650
	4	29.64	32.91	34.07	-	-	-	7.8414
2-06-73	1	29.45	47.07	43.05	44.93	25.08	30.13	21.7740
	2	33.24	38.85	36.85	40.15	40.03	40.20	23.1930
	3	32.62	35.43	35.70	37.32	38.83	37.58	22.0146
	4	33.95	36.78	36.98	-	-	-	8.6814
2-07-73	1	42.14	47.85	43.93	42.91	24.74	30.44	22.4418
	2	32.21	37.72	36.79	39.39	40.19	30.73	22.9278
	3	28.09	31.20	31.99	33.30	34.24	32.95	19.4550
	4	30.81	35.64	36.84	-	-	-	8.4078
2-10-73	1	55.58	59.17	54.66	52.42	29.40	36.74	27.6714
	2	42.39	45.53	42.55	45.76	44.52	44.89	26.6016
	3	37.76	38.49	37.62	38.32	39.58	37.73	22.9650
	4	36.67	35.91	33.54	-	-	-	8.6196

T-BAR PLAYA TEST SITE

DATE	STATIONS	% BY VOLUME AT VARIOUS DEPTHS						TOTAL INCHES IN PROFILE
		6"	12"	24"	36"	48"	60"	
2-13-73	Station 1	38.72	45.00	41.55	40.92	23.52	28.17	21.1224
	2	41.51	47.00	44.91	47.68	48.60	48.97	28.1298
	3	33.32	36.24	36.29	37.04	38.15	36.41	21.9204
	4	35.87	37.95	38.70	-	-	-	9.0732
2-16-73	1	40.31	46.24	43.34	42.61	23.50	28.95	21.8010
	2	37.67	41.60	40.89	43.80	43.39	44.66	25.4850
	3	31.95	35.18	34.83	37.36	36.71	36.90	21.5238
	4	29.84	33.70	34.48	-	-	-	7.9500
2-19-73	1	41.65	47.75	44.95	43.53	25.17	29.93	22.5936
	2	35.52	39.67	38.53	41.01	41.76	41.69	24.0702
	3	34.62	34.74	34.06	35.93	37.16	35.65	21.2976
	4	33.68	34.59	35.99	-	-	-	8.4150
3-03-73	1	45.81	68.59	48.29	59.44	26.89	31.47	26.7948
	2	30.72	34.91	35.29	34.31	38.46	38.43	21.5166
	3	28.43	33.52	34.34	35.63	36.03	35.83	20.7366
	4	30.10	35.07	37.10	-	-	-	8.3622
3-05-73	1	38.76	45.07	43.76	44.01	27.08	29.02	22.2942
	2	32.23	39.45	40.32	41.95	43.60	43.32	24.6036
	3	29.05	32.72	33.07	35.20	36.97	36.01	20.6562
	4	30.82	35.02	36.69	-	-	-	8.3532
3-13-73	1	40.92	46.90	44.21	43.32	25.83	30.48	22.5300
	2	30.29	38.87	38.59	40.38	41.57	41.72	23.6208
	3	30.51	34.50	34.71	36.31	37.97	37.28	21.4890
	4	wet						

T-BAR PLAYA TEST SITE

DATE	STATIONS	% BY VOLUME AT VARIOUS DEPTHS 6"	12"	24"	36"	48"	60"	TOTAL INCHES IN PROFILE
4-03-73	Station 1	31.31	43.50	43.31	43.15	25.87	30.67	21.6486
	2	26.09	35.86	36.91	38.69	41.65	41.39	22.7538
	3	25.15	31.15	33.21	36.02	36.93	38.09	20.6880
	4	27.28	32.26	34.67	-	-	-	7.7328
4-10-73	1	33.13	44.77	44.18	45.15	26.06	31.62	22.3800
	2	29.33	37.16	37.40	41.25	42.04	41.74	23.4810
	3	22.42	29.04	30.88	33.08	35.69	35.37	19.2900
	4	25.03	30.99	34.42	-	-	-	7.4916
4-17-73	1	24.56	39.28	41.56	42.41	25.11	29.71	20.4852
	2	28.35	38.36	40.29	43.04	44.49	45.40	24.7890
	3	20.27	28.66	30.46	33.10	35.46	35.58	19.0878
	4	18.53	27.86	31.89	-	-	-	6.6102
4-20-73	1	29.99	43.97	45.46	45.25	27.38	33.38	22.6140
	2	24.93	34.53	36.88	38.70	40.58	41.24	22.4556
	3	19.18	27.52	30.67	32.44	35.26	34.57	18.7548
	4	19.09	28.55	32.09	-	-	-	6.7092
4-24-73	1	22.55	36.98	39.96	43.07	24.64	29.97	20.0886
	2	20.52	32.65	36.38	38.83	40.57	40.87	21.9882
	3	20.42	29.44	33.15	36.60	38.38	39.07	20.6556
	4	19.18	27.21	32.62	-	-	-	6.6978
5-02-73	1	23.21	36.90	40.38	40.56	23.27	29.86	19.6950
	2	17.41	29.59	35.21	37.88	39.99	41.25	21.3396
	3	15.01	25.46	29.96	32.07	35.46	35.06	18.3342
	4	17.73	24.13	27.73	-	-	-	5.8392

T-BAR PLAYA TEST SITE

DATE	STATIONS	% BY VOLUME AT VARIOUS DEPTHS 6"	12"	24"	36"	48"	60"	TOTAL INCHES IN PROFILE
5-09-73	Station 1	22.37	35.33	39.90	42.15	23.52	29.47	19.6668
	2	13.35	25.58	32.44	35.39	38.88	48.19	20.9238
	3	14.41	23.57	28.69	32.58	34.62	35.29	18.0204
	4	15.63	21.57	26.24	-	-	-	4.3808
5-12-73	1	16.96	31.84	37.46	39.39	22.59	28.18	18.2424
	2	16.94	25.94	31.47	36.36	37.22	37.55	19.6848
	3	12.65	20.46	26.57	31.27	34.65	34.21	17.1906
	4	14.87	20.57	22.87	-	-	-	4.8708
5-16-73	1	24.86	33.98	37.03	41.41	23.21	29.28	19.2420
	2	21.74	28.24	34.48	37.71	39.78	40.46	21.2904
	3	20.25	23.45	28.37	32.45	35.52	35.12	18.3972
	4	16.61	20.75	23.95	-	-	-	5.1156
5-19-73	1	20.01	33.97	37.72	41.52	23.33	29.01	19.0284
	2	19.28	27.79	33.95	38.55	39.75	40.32	21.1326
	3	17.61	22.87	28.15	32.22	34.57	34.49	17.9604
	4	16.00	21.41	22.62	-	-	-	4.9608
5-21-73	1	24.58	34.94	37.46	36.69	22.40	28.35	18.5592
	2	21.14	24.59	31.27	36.10	38.71	38.62	20.1078
	3	14.00	21.26	24.88	30.15	32.66	32.64	16.5552
	4	14.46	20.49	22.03	-	-	-	4.7406
5-24-73	1	34.13	39.16	39.35	41.14	22.32	29.37	20.2950
	2	26.10	29.51	30.56	35.30	37.75	36.40	20.1366
	3	23.94	24.81	25.63	31.42	33.91	33.29	17.8350
	4	20.64	21.53	21.98	-	-	-	5.1678

T-BAR PLAYA TEST SITE

DATE	STATIONS	% BY VOLUME AT VARIOUS DEPTHS 6"	12"	24"	36"	48"	60"	TOTAL INCHES IN PROFILE
5-27-73	Station 1	28.63	36.50	37.81	39.28	21.32	27.51	19.0182
	2	19.18	27.95	31.27	35.27	37.31	38.19	19.8726
	3	19.50	22.99	24.49	30.60	41.67	32.28	18.0342
	4	16.51	21.15	20.98	-	-	-	4.7772
6-02-73	1	21.94	32.22	35.10	37.46	21.10	27.06	17.7360
	2	17.60	27.14	29.16	33.09	35.98	36.42	18.8424
	3	15.60	20.45	22.93	28.94	32.35	33.33	16.2690
	4	13.36	17.51	-	-	-	-	1.8522
6-06-73	1	17.40	30.51	33.26	36.16	19.47	26.35	16.7034
	2	15.86	24.62	27.69	32.34	35.67	35.86	18.2160
	3	14.74	17.89	21.19	25.83	30.39	31.95	15.0798
	4	12.12	15.41	18.75	-	-	-	3.9018
6-15-73	1	22.51	30.57	31.02	32.71	23.79	21.54	16.2720
	2	16.70	20.66	25.59	27.07	30.77	34.14	16.3500
	3	15.47	18.09	19.62	22.18	28.07	31.14	14.1348
	4	11.98	18.48	17.06	-	-	-	3.8748
6-19-73	1	20.92	30.94	31.83	32.46	17.81	24.04	15.8484
	2	16.21	24.29	25.06	24.19	31.18	34.49	16.2204
	3	13.81	19.70	18.96	22.85	28.95	30.32	14.1402
	4	11.58	18.16	17.29	-	-	-	3.8592
6-22-73	1	19.83	30.84	31.84	32.74	18.23	24.13	15.8730
	2	17.74	27.96	23.85	24.03	31.79	35.21	16.5276
	3	13.76	20.01	19.46	23.48	28.95	30.01	14.2542
	4	13.14	17.48	16.42	-	-	-	3.8076

TABLE B

DOUBLE LAKES TEST SITE

DATE	STATIONS	% BY VOLUME AT VARIOUS DEPTHS						TOTAL INCHES IN PROFILE
		6"	12"	24"	36"	48"	60"	
12-30-72	Station 1	31.74	36.47	36.48	28.71	32.65	-	15.8334
	2	20.54	31.48	32.08	33.34	-	-	10.9716
1-20-73	1	40.00	41.47	40.24	31.77	36.48	-	17.9070
	2	28.53	34.67	35.92	37.20	34.60	-	16.7184
1-24-73	1	35.11	42.93	42.18	34.56	38.16	-	18.4704
	2	28.46	37.08	38.11	38.12	34.77	-	17.2524
1-27-73	1	31.50	45.37	42.92	35.92	37.51	-	18.5742
	2	26.57	34.32	37.29	36.52	35.05	-	16.7166
1-30-73	1	29.25	42.55	42.00	36.06	36.24	-	18.0240
	2	23.01	34.20	38.49	38.06	36.47	-	16.9950
2-03-73	1	44.97	48.67	47.10	37.25	43.12	-	20.9148
	2	32.69	39.76	41.00	42.90	40.25	-	19.2450
2-06-73	1	40.29	43.17	42.67	34.22	38.56	-	18.8616
	2	31.91	39.54	42.89	44.66	42.90	-	19.9410
2-07-73	1	43.34	48.22	48.02	39.39	43.48	-	21.2004
	2	32.35	38.23	41.68	43.56	41.04	-	19.3884
2-13-73	1	42.38	46.80	44.17	37.50	42.32	41.61	25.2228
	2	33.32	38.80	40.30	41.27	40.05	-	18.9216
2-16-73	1	44.60	46.84	45.97	37.00	43.00	-	20.6028
	2	33.90	38.71	41.12	43.87	41.09	-	19.4862
2-19-73	1	44.22	47.22	45.41	38.12	41.66	42.35	25.5912
	2	31.17	36.81	39.26	41.80	39.70	-	18.5700

DOUBLE LAKES TEST SITE

DATE	STATIONS	% BY VOLUME AT VARIOUS DEPTHS 6"	12"	24"	36"	48"	60"	TOTAL INCHES IN PROFILE
2-23-73	Station 1	43.81	41.15	44.37	36.82	40.81	-	19.7376
	2	31.80	36.21	38.90	40.32	39.28	-	18.3006
3-03-73	1	31.88	47.05	45.82	38.07	42.81	-	19.9398
	2	30.77	36.45	39.00	38.25	40.34	-	18.1440
4-03-73	1	38.82	42.00	41.69	35.24	39.24	-	18.7896
	2	25.25	31.52	34.92	37.55	37.85	-	16.6446
4-10-73	1	34.09	42.57	42.66	35.76	41.01	-	18.9312
	2	24.09	33.43	37.93	41.07	40.38	-	17.7768
4-12-73	1	36.70	42.50	42.90	35.60	39.95	-	18.9660
	2	26.22	34.19	38.00	41.13	41.12	-	18.0546
4-17-73	1	30.61	42.57	42.51	34.45	40.62	-	18.6204
	2	21.46	31.05	36.18	39.84	39.50	-	17.0130
4-18-73	1	34.14	42.48	43.46	36.45	40.59	-	19.0572
	2	26.82	35.80	38.88	42.46	43.03	-	18.6816
4-20-73	1	31.67	41.86	42.32	34.40	39.43	-	18.3498
	2	23.04	31.10	36.11	38.77	38.02	-	16.7964
4-24-73	1	35.48	41.99	41.39	33.26	40.93	-	18.5178
	2	27.56	35.75	40.96	44.89	44.81	-	19.4886
5-02-73	1	-	-	-	-	-	-	16.9566
	2	21.03	37.32	40.01	33.06	39.06	-	16.9566
5-05-73	1	25.88	36.95	40.65	33.26	39.00	-	17.3190
	2	19.36	29.15	34.18	37.18	37.10	-	15.9258
5-09-73	1	20.81	34.09	40.26	31.88	37.66	-	16.4700
	2	16.68	28.27	34.38	37.29	37.32	-	15.7758

DOUBLE LAKES TEST SITE

DATE	STATIONS	% BY VOLUME AT VARIOUS DEPTHS 6"	12"	24"	36"	48"	60"	TOTAL INCHES IN PROFILE
5-12-73	Station 1	28.93	36.10	38.66	31.22	37.99	-	16.8462
	2	15.80	28.63	34.85	38.56	38.75	-	16.1250
5-13-73	1	28.87	35.90	38.76	30.74	37.60	-	16.7382
5-16-73	1	30.20	35.81	38.47	30.88	37.37	-	16.7670
	2	21.19	28.67	33.32	37.46	37.44	-	15.9780
5-19-73	1	29.15	35.61	38.90	30.75	38.46	-	16.8588
	2	16.71	27.18	33.02	37.33	37.45	-	15.5694
5-21-73	1	28.57	33.46	38.75	30.67	37.57	-	16.5606
	2	17.72	27.76	32.20	37.38	36.88	-	15.5040
5-24-73	1	33.32	35.45	37.45	30.25	38.30	-	16.8462
	2	28.26	33.67	34.33	37.86	37.48	-	16.8762
5-27-73	1	38.44	43.40	46.84	37.64	45.40	-	20.4960
	2	22.93	31.36	34.14	39.01	37.91	-	16.5846
6-02-73	1	31.08	37.75	42.72	39.39	45.35	-	19.4250
	2	25.49	31.55	32.41	37.23	37.67	-	16.2996
6-15-73	1	19.03	29.76	32.03	27.40	37.45	-	14.5530
	2	14.18	21.23	28.18	33.54	37.18	-	13.9926
6-19-73	1	17.76	28.47	30.16	25.38	35.53	-	13.7022
	2	11.54	21.26	26.13	33.11	35.77	-	13.3692
6-22-73	1	21.32	29.26	28.91	24.81	35.03	-	13.6848
	2	9.13	18.88	24.76	29.15	34.25	-	12.2598
6-26-72	1	20.15	28.97	29.24	24.00	34.63	-	13.4916
	2	10.78	19.05	24.34	31.94	36.24	-	12.8922